Bk. 3

PROPAGATED ACTIVITY

3

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RECORD

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FEDERAL SUPPLY SERVICE
(GPO)

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Computations of Propogated Activity

Record

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This record begun Nov. 6, 1963,
but restrospective to Q dependence notes
in other notebook (July 1963)

Table of Contents on p. 5

Began to develope new program series

WXR 701C 8/5/63
WXR 703C
WXR 706C

{.109 (7/26/63)
Based upon success of 732{.106 (7/22/63)
with Berman Weiss Program

732.100 series explored a compartmental model to mimic action potential in a single compartment.

WXR 700 series set out to propogate in chain of compartments

Purpose was to compute for <u>active</u> and <u>passive</u> chain and plot results.

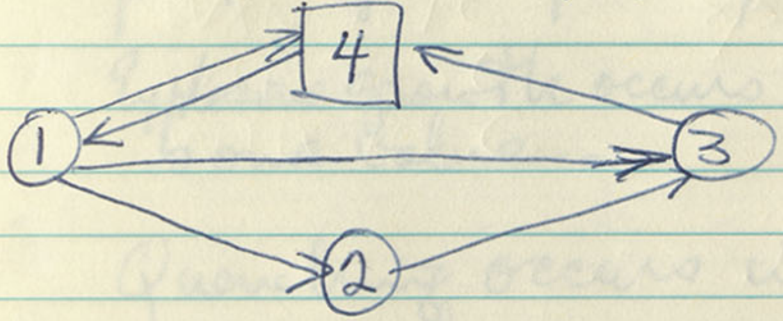
Subroutine WXR71C : Runge-Kutta for passive chain
→ WXR74C → WXR78C

Subroutine WXR72C : plotting subroutine based initially upon Berman-Weiss 63-E
modified → WXR75C → WXR76C

Subroutine WXR73C : Runge-Kutta for active chain
→ WXR77C

The model of 732.109 was essentially this
(7/26/63)

(preliminary notes dated 7/19/63)



$Q_4(0) = 50.$ (source compartment for growth feeding flux)

$$\lambda_{14} = (4.)\,Q_2$$

$$\lambda_{21} = (2.)\,Q_1$$

$$\lambda_{32} = 15.$$

$\lambda_{31} = (20.)\,Q_3$ This produces quench

$$\lambda_{43} = 5.$$

$\lambda_{41} = 2.$ — approx: exactly $(4.)\,Q_4 Q_2$

$$\dot{Q}_1 \cong (200.)\,Q_2 - (2.)(Q_1)^2 - (20.)\,Q_1 Q_3$$

$$\dot{Q}_2 = (2.)(Q_1)^2 - (15.)\,Q_2$$

$$\dot{Q}_3 = (15.)\,Q_2 + (20.)\,Q_1 Q_3 - (5.)\,Q_3$$

$$\dot{Q}_4 = (2.)\,Q_1 + (5.)\,Q_3 - (4.)\,Q_2 Q_4 \qquad \left(\frac{\dot{Q}_4}{Q_4} \approx 0.\right)$$

Threshold believed to be due to dependence of Q_2 upon square of Q_1

Explosive growth occurs when Q_2 exceeds some value.

Quenching occurs when Q_3 exceeds some value.

One difficulty was that peak of this action potential tended to be very sensitive to relation between explosive rate and quenching rate, as well as rates governing Q_2 & Q_3.

Attempted to correct this with something akin to equilibrium potential.

By making λ_{31} depend upon λ_{14}, but got snafu because Berman-Weiss program does **not** sustain Q dependence through a dependence relation between two parameters.

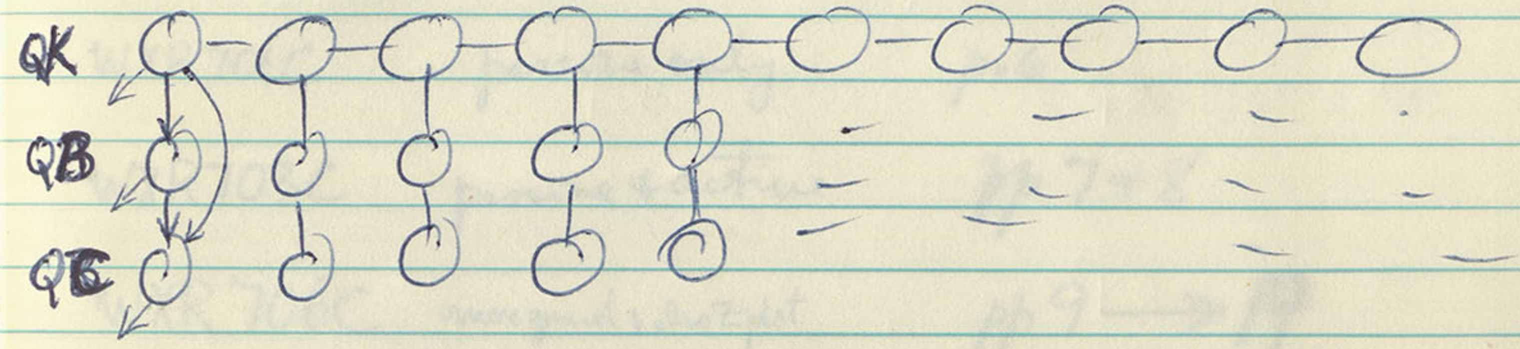
At this point, decided to press own program and get away from strict compartmental model & strict limitations of Berman Weiss program.

V
B
C

"growth Flux" ~ "Feeding Flux" ~ "Na Flux"

"Quench Flux" ~ "K Flux"

Model in WXR73C was (9/26/63)



for j not at either end

$$\dot{(QK)}_j = \begin{cases} (RACT)(QB)_j(1.-QK_j) - (1.+2.G)(QK_j) + G(QK_{j-1}+QK_{j+1}) \\ -(QUENCH)(QC)_j(QK)_j \end{cases}$$

$$\dot{(QB)}_j = (RINB)(QK_j)^2 - (ROUTB)(QB_j)$$

$$\dot{(QC)}_j = (RINC)(QB_j) - (ROUTC)(QC_j)\ \overset{?}{+}\ QUENCH(QC)(QK)$$

not used at first but later added to WXR77C

see p. 10

factor (1.-QK) corresp to equilib-pot. at 1.
QB is variable governing "growth"
RACT is ~~facto~~ rate const "

QC is variable governing "quench"
"QUBNCH" is rate const " "

p. 26 reviews Subsits. 73, 77, 79

Following pages review development of programs

WXR701C	passive only	p. 6
WXR703C	passive & active	pp 7 & 8
WXR706C	more general; also Z plot	pp 9 → 19
WXR707C	"	20 — 27
WXR709C	"	23 — 27

WXR 780C	began axon-soma-dendrites	28, 31	
WXR 781C	continued "	35 — 37 — 41	
WXR 783C	mod. & extended (NEJ NSP)	38 →	
WXR 785C & 786C	similar with ACUBE	42	
	add AFPOS & EQJ	48	
82C	Call argument corrected	50 52	also BTOC RINC dropped

WXR 791C with WXR82C, 91C, 92C	corrected DQ (JS)	61	79

Chronology of WXR701C & subroutines

first attempts were 701C 8/5/63 prelim main program
71C 8/5/63 passive Runge Kutta
72C 8/13/63 mod of B·W·63E

Lessons from diagnostics:

8/15/63

Printer symbols by means of Argus ALF variables

Berman-Weiss 63E provides ~~for~~ many complications not met here

∴ decided to write new program WXR75C

Alphanumeric words are 8 charatters

∴ read with A8 for PROGNO

Also various small points in developing input formats

WXR71C compiled on first attempt.

9/18/63 discovered trouble due to fact that COMMON was being used, but forgot to dimension the common variables in subroutines which did not use them.

9/18/63 discovered error in Runge Kutta (electrotonic flow incomplete) states 450, 460 & 480 of WXR71C were incomplete.

9/23/63 finally worked successfully: 701C with 71C & 72C passive electrotonus.

Chronology of WXR703C & subroutines

10/1/63

WXR75C new plot subroutine
introduced rescaling by factor of two when off scale.
preprocessing still in master program.

WXR74C mod of WXR71C passive Runge Kutta
introduced HAFDEL and DELSIX from main program

10/2/63

WXR73C Runge Kutta for active chain
also uses HAFDEL and DELSIX as well as DELT and G
(minor errors)

10/3/63 – 10/10/63

Did considerable polishing & added IFTEST outputs while trying to correct trouble ultimately traced to failure of Common.

10/11/63 Recompiled with Arguments. No Common
No Equivalence

WXR73C compiled OK, but later discovered statement 480 was incomplete
WXR74C " "
WXR75C " " , but minor goof in vertical grid specification
WXR703C " " & worked.

10/13/63 got local response but not good spike

RACT = 200. DZ = .5, NZ = 10
QUENCH = 20.

RINB = 20.
RINC = 15.
ROUTB = 15.
ROUTC = 5.

Part of trouble was that statement 480 was incomplete, such that compartments 2 thru 9 were passive

0.3 RACT implies that peak QB ≈ .15
but this was only an early guess
and may need to be changed.

should be (20)(QBpeak) RACT
+(20)(QCpeak) QUENCH

10/17/63 increased RACT to 400.
C QUENCH to 100.
got larger spikes but slow decline

10/3/63

```
G = 1./(DZ*DZ)

TWOJJ = 4.*G + .3*RACT + 2.

NSTEP = TWOJJ *DT + .8

XND = NSTEP

DELT = DT/XND
```

WXR73C had statement 480 corrected 10/15/63, now hot.

Results 10/15/63 A propogated, but Quench was poor
spike stayed up.

142 sec

Here RACT = 400.
QUENCH = 20. but Quench did not
RINC = 5. feed QC

10/15/63 B

increased RINC to 15.
QUENCH to 60.

142 sec

got declining phase, but too gradual

10/17/63 A

decreased RACT to 200.

got low, slow spike

Chronology of WXR706C & subroutines

10/16/63

Incorporated a number of improvements over 703C

Generalized to permit plot vs Z as well as vs T

Preprocessing for plot is in plot subroutine WXR76C

WXR78C passive Runge Kutta, same as WXR74C out of WXR71C

WXR77C active Runge Kutta, " " " " 73C

WXR76C plot routine works in general for

ARG-(VA, VB, VMIN, VMAX, NPLP, NSPACE, NGRID, ABSCIS)

WXR706C formats & controls for more general setup.

NTZSTP = NT * NZ * NSTEP

tends to be 20 times the running time in sec

10/18/63 test failed because NSTEP = 0.

added statement 311 to 706C to prevent this in future

10/21/63 trouble in 706C traced to

NP still present from 703C, which should have been changed to NPLT

fixed by adding 353 NP = NPLT

10/21/63 B worked with RACT = 600.

QUENCH = 100.

got peak followed by slow decline to plateau

Therefore revised WXR71C to strengthen Quench.

```
480  DQ(JZ,JR) =

  G*[A(JZ-1) + A(JZ+1) - A(JZ) - A(JZ)] - A(JZ)
  + RACT*B(JZ)*[1.1 - A(JZ)]
  - QUENCH*A(JZ)*C(JZ)                              5 mult.
```

could rearrange to following form

```
                 G+G
  -A(JZ)*[1. + 2.*G + RACT*B(JZ) + QUENCH*C(JZ)]
  + 1.1*RACT*B(JZ) + G*[A(JZ-1) + A(JZ+1)]
                                                    6 mult.
```

10/23/63 WXR77C

$$450 \quad DQ(1,JR) = \left\{ \begin{aligned} & G * [A(2) - A(1)] - A(1) \\ & + RACT * B(1) * [1.1 - A(1)] \\ & - QUENCH * A(1) * C(1) \end{aligned} \right.$$

factor of A(1) added in WXR79C see p.23

Similarly 460 & 480

$$\text{also } 466 \quad DB(JZ,JR) = \left\{ \begin{aligned} & RINB * A(JZ) * A(JZ) - ROUTB * B(JZ) \\ & - QUENCH * B(JZ) * C(JZ) \end{aligned} \right.$$

$$467 \quad DC(JZ,JR) = \left\{ \begin{aligned} & RINC * B(JZ) - ROUTC * C(JZ) \\ & + QUENCH * C(JZ) * [A(JZ) + B(JZ)] \end{aligned} \right.$$

dropped this in WXR79C see p.23

Note autocatalytic quench

also QB is quenched as well as QK

Could weaken autocatalytic term

or could leave this & weaken actual quench by multiplying B(1) into it.

But may loose refractory period this way.

at peak of spike $QB \approx .03$

$QC \approx .2$ grows to 1.06 in ①

.89 in ④

peak in ①	②	③	④	⑤	⑥
QK = .69	.605	.606	.610	.611	.611
QB = .033	.029	.030	.030	.029	.029
QC = .12	.127	.182	.16	.144	.13)
later peak QC = 1.06	.89	.897	.901	.903	.903

10/22/63 63706.0005 PROBNO

A

Successful run
overquenched

NTZSTP = 4880
Running time = 218 sec

RACT = 600.
QUENCH = 50.
RINC = 10.

pretty good peak : amplitude ≃ 0.6
down slope steeper than up slope.

Plotting format works fine, for some time, by now.

10/23/63 reduced QUENCH to 20.
63706.0006
Did not work well
Trouble in active Runge Kutta
or Machine failure?

Time out for Stanford Press Galley Proofs.

11/1/63 63706.0007 restored quench to 50.

pretty good spike
down slope steeper than up slope.

This really duplicated 63706.0005
except for DT = .02 here
while it was .04 in

both had DZ = .5

This pair demonstrates threshold well

for IC = 0.2

VA dips to .102

and then climbs to peak of .565

@ peak QB = .022
QC = .22

11/4/62   63706.0009   I.C. = .2
.0010   I.C. = .1

here DZ was reduced to 0.2
DT - - - 0.01
question was threshold

RACT = 600.
QUENCH = 50.

NTZSTP = 1740 each or 3480 for both

Running time for both was 171 sec ~~x~~ $\frac{3480}{20}$ ✓

for IC = 0.1 in one of ten compartments (DZ = 0.2)

This is below threshold

VA does not fall quite as fast as VB
QB rises to peak value of .0003 at T = .05
QC ~ slowly ~ .00042 at T = .30

by that time VA has dropped to .0325
while VB .0151
QB - - - .00016

QC holds .00042 from T = .30 to T = .48
during which time ~~VA~~ QB has dropped to .00013
VA .031
VB .010

at T = .56, VA is barely beginning to climb again, although QB & QC are stationary!..

Prob reflecting neighboring cpts.

Can estimate near threshold ~~pseudo~~ steady state ←
This is with load, neighboring pts also nonlinear

KT =	11	14	18	22	58
VA =	.0944	.0933	.0944	.0975	.282
VB =	.00126	.00123	.00120	.00121	.0064
VC =	.00104	.00137	.00178	.00217	.0162

Take A(1) = .096
A(2) = .08
B(1) = .0012
C(1) = .002

G = 25.
RACT = 500.
RINB = 2.
RINC = 10.

QUENCH = 40.
ROUTB = 15.
ROUTC = 5.

$$\cancel{D}Q = \left.\begin{array}{l} 25(.08-.096)-.096 \\ +500(.0012)(1.1-.096) \\ -40(.096)(.002) \end{array}\right\} = \left\{\begin{array}{l} -.4-.096 \\ +.6 \\ -.008 \end{array}\right\} = \left\{\begin{array}{l} -.496 \\ +.6 \\ -.008 \end{array}\right.$$

$$\sim +.1$$

11/6/63 63706.0011

Three cases with I.C. = .3, .2, .1 in ①

Here RACT = 500. reduced from previous 600.
QUENCH = 40. reduced from previous 50.

3*NTZSTP = 3*1740 = 5220. 5220/20 = 261
actual running time was 254 sec

IC = .3 above threshold
.2 very close to thresh: dipped to .09 & regained .2 at T=.50
.1 below thresh.

for IC=.3 in ① (DZ=0.2, NZ=10)

dipped to 0.163
Then rose to peak of 0.595 at T=.45

cpt ② rose to peak of 0.620 at T=.47 .636

QB=.030 .0336
QC=.182 .127
in ④

Conclude that RACT=500. may be a little too sluggish
but, first, should compare with I.C. in five cpts
& in all ten cpts.

11/7/63

WXR706C

Stock taking today. (pp 14-19)

Pulled production run because decided to decrease NSTEP & TWOJJ to take account of QB and QC values actually found at peak.

i.e. for QB = 0.03
QC = 0.20

should get $\lambda_{jj} = 1. + 2.*G + .03*RACT + 0.2*QUENCH$

$TWOJJ = 2. + 4.*G + .06*RACT + 0.4*QUENCH$

Because intend to try smaller QUENCH to permit QK and QB to grow larger, figure on QB = 0.05

Decide to incorporate new calc. in WXR707C using 0.1 as coeff of RACT.

Also, add only 0.5 at statement 310 for NSTEP calc.

At present, this will ~~have~~ cut computation time in half without loss in accuracy. May need to review later.

Also define NABC = IFTEST - 10 to determine print output of VAZ, AB, AC, VBZ. This separates print output from plot DT.

DZ = .5

done p.23

Quench could be made less steep by making proportional to V^2 or to $QK*QB$, but this will result in less effective refractory period.

First try simply smaller QUENCH coefficient.

Examine value of DQ for compartment ④ in 63706.0007

steep slope	peak
KT=26, TK=0.50	KT=33, TK=0.64
A(4) = 0.294	A(4) = 0.61
A(3) = 0.606	A(3) = 0.064
A(5) = 0.072	A(5) = 0.284
B(4) = 0.005	B(4) = 0.030
C(4) = 0.0035	C(4) = 0.16

→ G = 4., RACT = 600., QUENCH = 50.

For peak DQ

$$\left\{\begin{array}{l} 4(\overset{-.87}{.35-1.22})-0.61 \\ +600(.03)(\overset{.49}{1.1-0.61}) \\ -50(0.61)(0.16)\end{array}\right\} = \left\{\begin{array}{l} -3.47-.61 \\ +600(.0147) \\ -50(.0976)\end{array}\right\} = \left\{\begin{array}{ll} -4.08 & \text{passive} \\ +8.82 & \text{feeding} \\ -4.88 & \text{quench} \\ \hline -0.14 & \end{array}\right.$$

$\lambda_{jj} = 9. + 18. + 8. = 35.$

twice $\lambda_{jj} = 70.$ whereas WXR706C set TWOJJ = 198.

too large

11/7/63

For steep part of slope (KT=26, TK=0.50) in ④

$$DQ \Rightarrow \left\{\begin{array}{l} 4(.678-.587)-.294 \\ +600(.005)(1.1-.294) \\ -50(.294)(.0035) \end{array}\right\} = \left\{\begin{array}{l} .364-.294 \\ +600(.004) \\ -50(.001) \end{array}\right\} = \left\{\begin{array}{ll} +.07 & \text{passive} \\ +2.4 & \text{feed} \\ -0.5 & \text{quench} \\ \hline +1.8 & \end{array}\right.$$

$\lambda_{jj} = 9. + 3. + .15 = 12.15$

Twice $\lambda_{jj} = 24.3$

compared with TWOJS = 198.

New formula gives

TWOJS = 18 + 60 + 20 = 98

(compare with 70 of previous page)

But this allows for larger B valued peak because of intended smaller Quench.

DZ=.2 —

11/7/63 17

Check DQ in 63706.0009 in ②

RACT = 600.
QUENCH = 50.
→ G = 25

A(2) = 0.582
A(1) = 0.562
A(3) = 0.536
B(2) = 0.024
C(2) = 0.142

$$DQ = \left\{\begin{array}{l} 25(1.1-1.16)-0.58 \\ +600(.024)(1.1-.58) \\ -50(.58)(.14) \end{array}\right\} = \left\{\begin{array}{l} -1.5-.58 \\ +600(.0125) \\ -50(.081) \end{array}\right\} = \left\{\begin{array}{r} -2.1 \\ +7.5 \\ -4.05 \\ \hline +1.35 \end{array}\right.$$

still climbing

Note that smaller DZ than in .0007

causes (a) larger G

(b) smaller $(2A(JZ) - A(JZ-1) - A(JZ+1))$

i.e. less difference between neighbors.

a little later (at time peak), biggest change would be drop in value of A(1), resulting in making passive term more neg. However passive term is comparable to previous case.

11/7/63 18

Check DQ in 63706.0011 in peak ④ of first I.C.

RACT = 500.
QUENCH = 40.
G = 25.

$A(4) = .636$
$A(3) = .551$
$A(5) = .564$
$B(4) = .0336$
$C(4) = .127$

$$DQ = \left\{\begin{array}{l} 25\overset{-.16}{(-1.27+1.11)} - .64 \\ +500(\cancel{.64})(.0336)\overset{.46}{(1.1-.64)} \\ -40(.64)(.127) \end{array}\right\} = \left\{\begin{array}{l} \overset{-4.}{\cancel{-2.5}}-.64 \\ +500(.0155) \\ -40(.081) \end{array}\right\} = \left\{\begin{array}{r} \overset{-4.64}{\cancel{1.56}} \\ +7.75 \\ -3.22 \\ \hline -.11 \end{array}\right.$$

11/7/63

Plan to compare

I.C. = 0.5 in ①

with I.C. = 0.1 in ①, ②, ③, ④, ⑤

with RACT = 600.
QUENCH = 40.

Also, compare I.C. = 0.2 in ①

with I.C. = 0.2 in all ① to ⑩

If wish to modify Quenching function

modify WXR77C → WXR79C

WXR707C → WXR709C

but first test WXR707C with a repeat of 63706.0011

for first initial condition

7/7/63

WXR707C

Same as 706C except that at

```
301  TWOJS = 4.*G +.1*RACT +2. +.4*QUENCH

310   NSTEP = TWOJS *DT +.5
```

and

```
169  IF(IFTEST-10) 173, 173, 170
170  NABC =IFTEST-10
171  KNABC = NABC
172  GO TO 180
```

~~410 IF(~~ 173 NABC=0

```
410  IF(NABC) 4250,4250,411
411  IF(KT-KNABC) 4250, 420, 412
412  KNABC = KNABC+NABC
413  GO TO 411
```

Test run 63707.0011 —— with IFTEST = 15
Same as 63706.0011 first I.C.

*Reduced running time from 85 to 58 sec
because reduced NSTEP from 3 to 2

Results differ only in 5th significant figure of falling phase of spike. i.e. negligible

Good looking spikes

Might possibly consider slowing falling phase by making quench $\propto A^2$

11/11/63 63707.0014

Four sets of initial conditions

NZ=4; DZ=0.2 ; RACT=600; QUENCH=30.

Cases	A	B	C	D
I.C.	0.3	0.3	0.2	0.2
	in ①	in ①②③④	in ①	in ① ② ③ ④
Spike in ①				
peak ampl.	.8788	.95614	.9059	.9425
KT	40	20	55	26
T	.39	.19	.54	.25
Spike in ②				
peak ampl	.9096	ditto	.9167	ditto
KT	41		55	
T	.40		.54	
Spike in ④				
peak ampl	.9537	ditto	.9415	ditto
KT	43		56	
T	.42		.55	

all have RACT=500.
QUENCH=40.

Good looking spikes but falling phase a little too fast.

11/11/63

Compare QB & QC of 63706.0012
.0013
with .0011

63706.0012 IC = 0.2 in 5 of 10 cpts

$$\left.\begin{array}{l} \text{peak } QK \text{ around } .70 \\ QB \simeq .04 \\ QC \simeq .2 \end{array}\right\}$$ but does vary with expt. say in 3rd & 4th

$$\left.\begin{array}{l} QK \simeq .65 \\ QB \simeq .036 \\ QC \simeq .12 \end{array}\right\}$$ say in 7th

$$\left.\begin{array}{l} QK = .82 \\ QB = .05 \\ QC = .12 \end{array}\right\}$$ in 10th,

---

63706.0013 I.C. in .2 in all

peak $QK = .792$
$QB = .047$
$QC = .217$

Compare anticipations on p. 14

See p. 10

In 77C, statement 480 was

```
DQ(JZ,JR) = { G*[A(JZ-1)+A(JZ+1)-A(JZ)-A(JZ)] - A(JZ)
            { + RACT*B(JZ)*[1.1 - A(JZ)]
            { - QUENCH*A(JZ)*C(JZ)
```

(11/18/63)

In first version of 79C, last term becomes

```
- QUENCH*A(JZ)*A(JZ)*C(JZ)
```

11/19/63

second version in 79C mod. deleted superfluous test print

450, 460, 480 back to 77C form except that 1.1 → 1.0

```
466 now DB(JZ,JR) = { RINB*A(JZ)*A(JZ) - ROUTB*B(JZ)
                    { - HAFQCH*B*C(JZ)
```

where HAFQCH = 0.5*QUENCH. This should steepen rise of spike & keep it going a little longer.

```
467 now DC(JZ,JR) = { RINC*B(JZ) - ROUTC*C(JZ)
                    { + QUENCH*C(JZ)*A(JZ)*A(JZ)
```

This should slow the fall of spike but not as much as A^2 in 480.

11/18/63 first version, 11/19/63 second version

Modify WXR 77C ⟶ WXR 79C
WXR 707C ⟶ WXR 709C

in 450, 460, & 480

make quench $\propto A^2C$

purpose is to slow falling phase of spike somewhat

in 467 delete the Quench B contribution to DC as superfluous. Did not make DC term proportional to A^2

set up 63709.0014 with NT=81 DT=.01
NZ=4 DZ=.2
IFTEST=15
otherwise same as 63707.0014

The result was almost symmetrical spike. The last part of falling phase seemed a little slow. A further mod. was carried out after this test, but first examine results of this test.

---

for each case RACT=600. RINB=2. RINC=10.
QUENCH=30. ROUTB=15. ROUTC=5.

A had	NIZ=1	VIZ=0.3
B	4	.3, .3, .3, .3
C	1	.2
D	4	.2, .2, .2, .2

11/22/63

Second version seems quite suitable for well shaped spike

Compare also VB + VC at time where QK first falls to ~~[illegible]~~

	.0014 first version			.0015 2nd version	
	A .265	B .298		A .252	B .288
time	.54	.34	time	.65	.41
VB	.0025	.004	VB	.0097	.013
VC	2.374	2.06	VC	.897	.909

Even here, for some value of VAZ, second version has larger VB and smaller VC than first version. This is what produces the slower fall than rise.

11/19/63 63709.0014 A,B,C,D

(first version of 79C)

	A	B	C	D
Time of peak in ①	.390	.19	.54	.25
Amplitude of peak	.9039	.9666	.9257	.954
VB	.0623	.0731	.0658	.068
VC	.3011	.1684	.2558	.155
				values at .24

11/22/63 63709.0015 ABCD

(Second version of 79C)

	A	B	C	D
Time of peak in ①	.44	.21		
Amplitude of peak	.87	.8937		
VB	.068	.0715		
VC	.18	.1356		
	average between .43 & .45			

Consider .10 τ after peak

	63709.0014		63709.0015	
63709.0014	A	B	A	B
~~Time~~ Time	.49	.29	.54	.31
peak	.47	.565	.62	.654
VB	.0126	.0235	.048	.054
VC	1.776	1.406	.81	.747

This shows that with second version, VB is still larger & also VC has not grown as large, both of which contribute to slower fall.

K.J

May want to compromise between
63707.0016
and 63709.0015

11/25/63 63707.0016

Test effect of reducing QUENCH to 20. in 77C

to compare with B ~~version~~ case of 14 and 15

79

also B case of 63707.0014

Shape came out pretty good. Peak exceeded 1.0

slightly flatter

~~63707.0014~~ ~~63~~

	63707.0014B	63707.0016(B)	63709.0014B	63709.0015B
	QUENCH = 30.	QUENCH = 20.	1st version QUENCH=30.	2nd version QUENCH=30.
15	.810	.820	.816	.717
16	.860	.874	.867	.761
17	.901	.921	.909	.801
18	.932	.959	.940	.834
19	.950	.987	.959	.860
20	.956	1.005	.967	.879
21	.950	1.015	.963	.890
22	.931	1.018	.949	.894
23	.901	1.015	.926	.891
24	.857	1.008	.895	.882
25	.800	.997	.856	.868
30	.366	.872	.565	.732
35	.0806	.603	.299	.529
40	.015	.285	.171	.345
45		.100		.220

In all of these examples -

RACT = 600.
RINB = 2.
RINC = 10.
~~QUENC~~
ROUTB = 15.
ROUTC = 5.

I.C. is 0.3 in all four Cpts.

for 79C may want to use smaller ROUTC

for 77C may want to use smaller ROUTB
or smaller Bquench

Try 63707.0021 with ROUTB = 5., QUENCH = 20.
.0022 RACT = 800. & above

Try 63709.0023 ROUTC = 2., QUENCH = 30.
.0024 RACT = 800. & above

Compare with .0015
63709.0025

RACT = 60. factor 10 smaller
RINB = 20. factor 10 larger
RINC = 2. factor 10 smaller & factor 2 larger
QUENCH = 15. factor 2 smaller
ROUTB = 15.
ROUTC = 5.

B fact 10 larger
C fact 2 larger
but C growth not doubled

11/29/63 **Review** 73, 77, 79

$\dot{A}$ = Passive + Agrowth − Aquench
$\dot{B}$ = Standard B − Bquench
$\dot{C}$ = Standard C + Cgrowth

in all cases
$$\begin{cases} \text{Passive} = G*(A_{j+} + A_{i+} - 2A_{ij}) - A_{ij} \\ \text{Standard B} = (\text{RINB})A^2 - (\text{ROUTB})B \\ \text{Standard C} = (\text{RINC})B - (\text{ROUTC})C \end{cases}$$

$$\text{Agrowth} = (\text{RACT})B(1.0 - A)$$

1.0 in 73 & early 77, late 79
1.1 in most late 77, early 79

in 73C
$$\begin{cases} \text{Aquench} = (\text{QUENCH})*C*A \\ \text{Bquench} = 0 \\ \text{Cgrowth} = 0 \end{cases}$$

in most 77C
Agrowth uses 1.1
Aquench same as 73C
Bquench = (QUENCH) * B * C
Cgrowth = (QUENCH) * C * (A + B)

79C first version made
Aquench = (QUENCH) * C * A^2
Cgrowth = (QUENCH) * C * A

79C second version
use 1.0
Aquench = (QUENCH) * C * A as in 73 & 77
Bquench = HAFQCH * B * C
Cgrowth = QUENCH * C * A^2

.0021 is best of 707 series

.0024 is best of 709 series

Note: Threshold may be changed somewhat.

Comparing 63707.0021 and 22 with 63707.0014B
and 16B

(16) reducing Quench from 30. to 20.
resulted in wider peak such that fall is very
slightly slower than rise.

---

(21) In addition
reducing RoutB from 15. to 5. caused a
more rapid rise and slightly skewed
peak.

a bit of this character.

This due to larger B values.

(22) In addition
Ract B increased from 600. to 800.
increased skewness

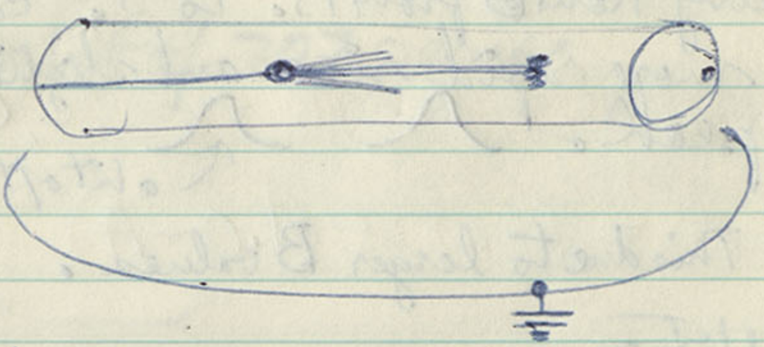
Now compare 63709.0023 & 24 with 63709.0015B
63709.0015B had pretty good peaks but final fall was too slow

(23) reduced RoutC from 5. to 2., This keeps C larger
as square goes off.
Succeeded in bring spike down more sharply.

(24) In addition
Increased RACT to 800.

increased rising rate
Got very good shaped spike

factor is different in axon than in soma: (depends on $r_i + r_e$ and $\frac{r_e}{r_i + r_e}$) see p. 30



1st compute V_i as already provided by previous methods. If external leakage were zero, then could assume that outer V_e is zero and outside neuron, $V_e \propto -V_i$

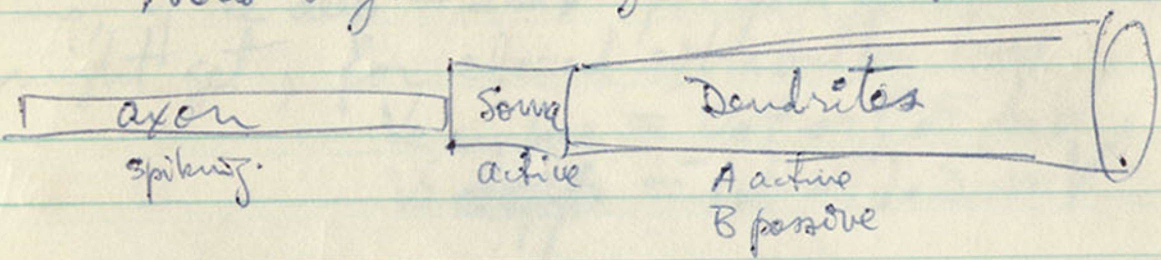
~~New comment~~ Extracellular r_e is approx [illegible] 1/35th of intracellular r_i, because peak $V_i \approx 70$ mV while peak $V_e \approx 2$ mV. The extrabulbar leakage is a larger resistance which will be regarded as negligible for V_i and V_m of Z+T. Also it appears (from checking Gordon's records) that the resistance from surface to zero contour (indifferent) is about 1/4 or 1/5 the resistance from axons near bulb ~~[illegible]~~ center to the zero contour.

(continue p. 29)

12/4/63

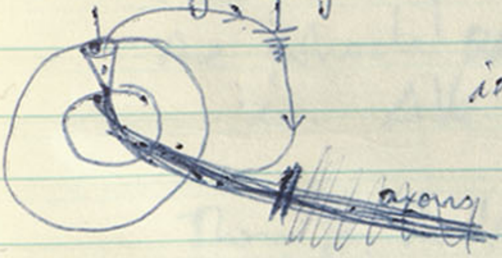
780

Now begin to roughout WXR~~801~~C



at first, won't aim at complete flexibility of parameters.
Could use larger delt while impulse is in axon & then reduce delt once it reaches soma, at least when dendrites are active. Probably not necessary when dendrites are passive.

First treat case where dendrites are passive, but try to provide for leakage path. around -



i.e. ~~say~~ we have five axonal $\Delta Z \approx 0.5$

i.e. $G = 4$

then soma, larger will be indicated by $\mu_{s,a} \ll \mu_{a,s}$

which corresp to ratio of lumped capacities

* This leads to suggestion of first ~~testing~~ safety factor of propogation of present action potential model.

Need only modify 79C to permit a change in one of the μ values.

as a fcn of T it would be $\boxed{(0.4)\Delta V_e}$ to add

thus, if Ve deep = −2mV for open extrabulbar loop
might get, for closed extrabulbar loop

$$V_e \text{ surface} = 0.4 \text{ or } 0.5 \text{ mV}$$
$$V_e \text{ deep} = -1.6 \text{ or } -1.5 \text{ mV}$$

This is assuming that extrabulbar loop resistance is large compared with r_e of cylindrical volume, so that ΔV_e (surface to deep) is unchanged. In this case, one ← would simply add 0.4 mV to all values of Ve(Z, [illegible]). This is probably the best approximation.

Alternative is to assume that extrabulbar loop draws enough current to reduce ΔVe (surface to deep). Then this is equivalent to imposing a steady current along r_e which ~~would~~ cause a linearly graded drop i.e. ΔVe is reduced to ~~$\frac{10}{11}$~~ $\frac{9}{10}$ if loop adds 10% conduct.

Then for the 1/5 voltage divider, get Ve surface = 0.36
and $V_{e_{loop}}(Z) = V_{e_{open}}(Z) + 0.36$ [illegible] $+ \frac{Z}{Z_{max}}(0.2)$

where Z = 0 at surface
Z = Zmax deep

$$V_{e_{loop}}(0) = V_{e_{open}}(0) + 0.36$$
$$= .36$$

$$V_{e_{loop}}(Z_{max}) = V_{e_{open}}(Z_{max}) + 0.56$$
$$= -1.44$$

ΔVe drops from −2mV to −1.8 mV

But this complication can be initially neglected.

Also, if want final Ve loop deep = −2mV
Ve loop surface = +.5mV / then $V_{e_{open\,deep}} = -2.5$

First time, let NJA = 4 with GA = 4
NJD = 5 with GD = 25
GSA = 1

VI = VK = intracellular potential on scale of 1. or 0.9

VEO = extracellular pot. (open loop) on mV scale

let FD = 3.
FA = .03 or could try also .1

suppose axon has 1μ core
dendrites have 5μ core, but there is one principal
& 4 or 5 secondaries.

$$\therefore \frac{g_i \text{ combined dendrites}}{g_i \text{ axon}} \approx \frac{5*25}{1} \approx 125$$

open loop

Thus, for axonal Z, might have $\frac{\partial V_e(Z)}{\partial Z} \approx -\frac{1}{3000}\frac{\partial V_i(Z)}{\partial Z}$

while for dendritic Z, would have $\frac{\partial V_e(Z)}{\partial Z} \simeq -\frac{1}{30}\frac{\partial V_i(Z)}{\partial Z}$

except in trunk, r_e may increase enough that

$\frac{r_e}{r_e+r_i}$ is no longer negligible.

Let J = 1 represent dendritic terminals
J = NJD ~~number of~~ most proximal dendritic cpt.
NJD = number of dendritic compartments in row, say 10
J = JS = soma compartment
J = JH = axon hillock segment
NJA = number of axonal cpts, including JH
J = ~~JA~~ NZ = JS+NJA = first axonal cpt.

This allows for VK(1) ≠ 0

Then VEO(1) = 0
VEO(2) = -3.*(VK(2) - VK(1)) = +3.*(VK(1) - VK(2))
for J > 2 to J = JS VEO(J) = VEO(J-1) + 3.*(VK(J-1) - VK(J))

VEO(JH) = VEO(JS) + .03*(VK(JS) - VK(JH))

and on to J = JA

12/5/63

for first tests, make minimal revisions of 709C
& subroutines

709C → 780C   for first tests
need not even increase time dimension

Card ① change NZ to NJD

Delete old input card 3 & associated material

Instead, read GA, GD, GSA, NSTEP, IFDACT,
IFPLAB

where IFDAB = -1 means dendrites active only; ~~0 means inactive~~
= 0 ~~or neither~~ means both active & passive
=+1 means only passive

IFPLAB = -1 means only plot A
= 0 means plot A & B
=+1 means plot only B

needs to be in input & subroutine argument.

Within 780C   NJA = 4   number of axonal cpts (see p. 30)
JS = NJD+1
JH = JS+1
NZ = JS + NJA
NLZ = NZ - 1   (& delete from subrt.
(all these should be added to input arguments)

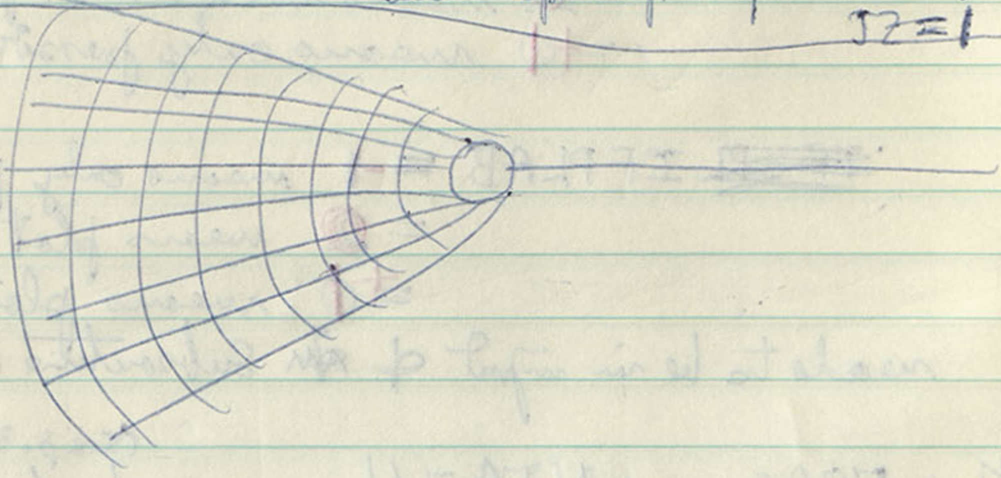
Completed punching up WXR 780C
80C plot
81C active dendrites
82C passive dendrites

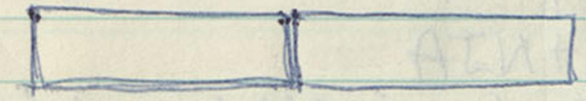
Notes for program.

May need to restore original initial condition flexibility VI(202)

* May need to put numbers in col 1 of the input cards, with I1 field and read & print

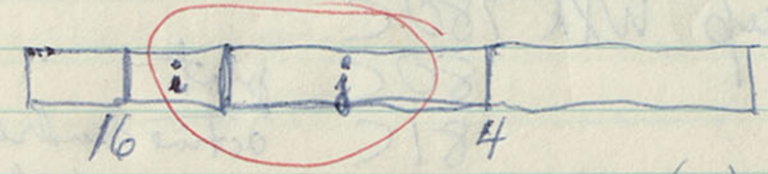
* Delete separate plot for KT=1 JZ=1





$\mu = \frac{g}{c} = 4$

g doubled c halved $\frac{g}{c} = 4\times4=16$



g_{ij} rel to midpts is factor $(3/2)$

$\mu_{ij} = 4\left(\frac{3/2}{1/2}\right) = 12$

$\mu_{ji} = 4\left(\frac{3/2}{1}\right) = 6$

Next see p. 33

12/6/63

63780.0001

Got a test run, although 82C had to be neglected because of minor error.

Got antidromic propagation to hillock, with block before at soma.

Block can be attributed to two factors

$$\frac{GSA}{GA} = \frac{1}{4}$$

also $GD = 25$

hence $\mu_{SS} \propto 25+4+1 = 30$

also $G_{DD} = 51$

while $\mu_{SH} \propto 1$

Also spike non-linearity may not be hot enough. Threshold in axon may be much lower than effective threshold in soma.

Therefore, for 63780.0002 increase RINB to 4. from 2.

Also, change GD to 4.

Also, could use cube relation for growth

Then need RINB about ten times as great.

If 5μ non-myelinated fiber has 1 mm = λ

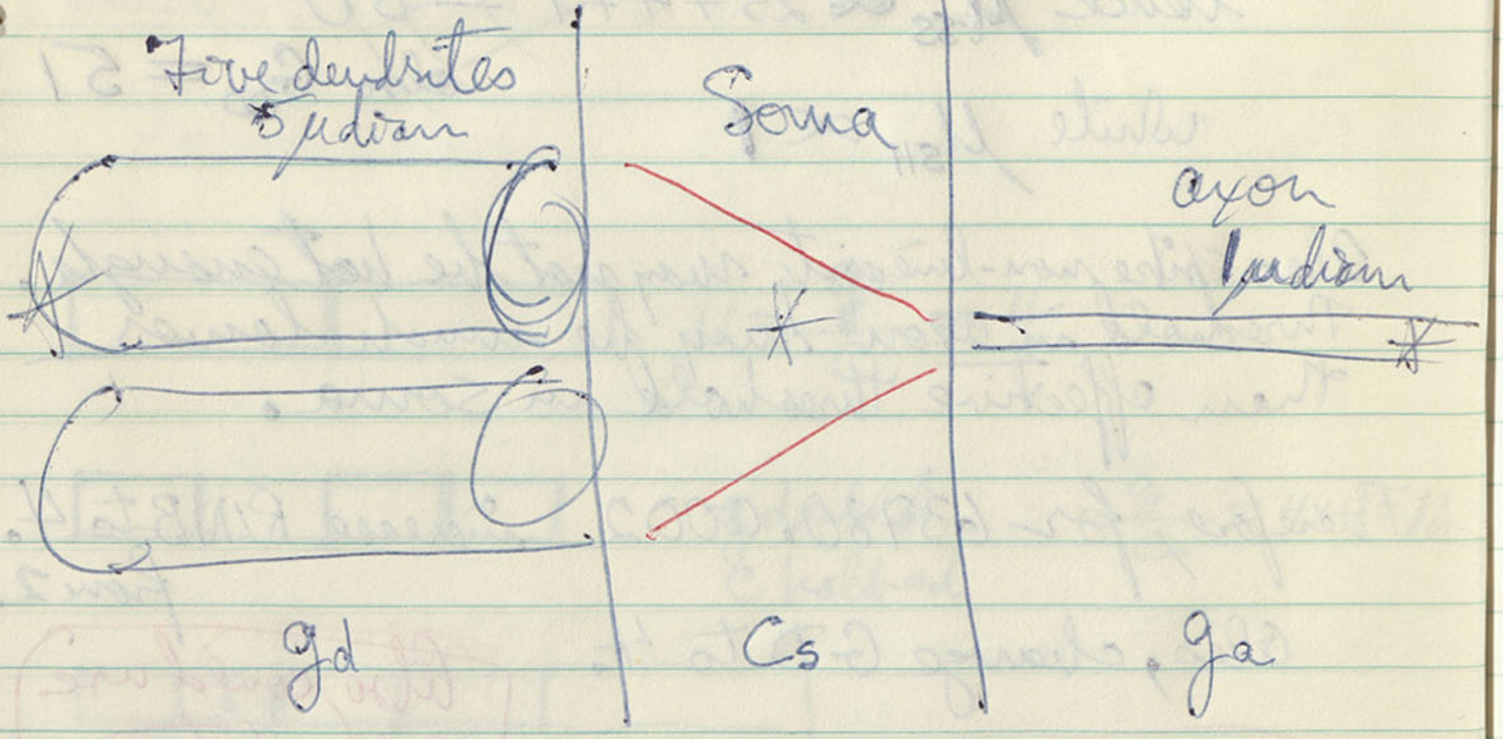
then 1μ " " " " " $\frac{1}{\sqrt{5}} \simeq 0.45$ mm = λ

~~Therefore~~ Then, axonal (1μ) ΔZ of 0.5 corresp to Δl = 0.225 mm

whereas dendrite (5μ) ΔZ of 0.2 corresp to Δl = 0.2 mm

i.e. ΔZ = 0.5 axonal $\approx$ ΔZ = 0.2 dendritic

Which agrees with 63780.0001



$\boxed{\text{for some } \Delta l}$

~~Between cd~~

Dendritic Compartments

then $C_d = 5$ per dendrite

$= 25$ for all dendrites

then $g_d = $ ~~[illegible]~~ $25 \times 4 = 100$ per dendrite

$=$ ~~125~~ 500 for all dendrites

between dendritic cpt

$$\mu_{ij} = \frac{g_d}{C_d} = \frac{500}{25} = 20$$

Axonal Compartments

let $C_a = 1$

let $g_a = 4$

between axonal cpts

$$\mu_{ij} = 4$$

~~Case ①~~ suppose capacity of soma $= C_s$, ~~and~~ and that we can treat $g_{ds} = g_{sd} = g_d$; $g_{as} = g_{sa} = g_a$

then $\mu_{ds} = \frac{g_d}{C_d} =$ $\mu_{as} = \frac{g_a}{C_a} =$

$\mu_{sd} = \frac{g_d}{C_s}$ $\mu_{sa} = \frac{g_a}{C_s}$

If $C_s = 4$, then $\mu_{sd} = \frac{500}{4} = 125$, $\mu_{sa} = \frac{4}{4} = 1$

If $C_s = \underset{20}{10}$, then $\mu_{sd} = \underset{25}{50}$, $\mu_{sa} = 0.\underset{.2}{4}$

(453) DQ(JS,JR) = GSD*A(JS-1) + GSA*A(J+1) ± etc

12/9/63

test 12/6/63 B overran memory limits.
There are 7 memory banks available
This was 2000 words into an 8th.

Checking back on earlier Octal Memory Maps
WXR701C & 703C where VATP was 100 x 10
the program reached into the 4th bank

WXR706C — 709C where VATP was 202 x 10
DQ was 202 x 4
The program reached into 7th bank.
i.e. I was nearer the limit than I realized.

In WXR780C, 82C added additional DQ 202 x 4
and additional BB + BC
& this overran limits. for active axon with passive dendrites

---

Plan to save ~~memory~~ reduce dimension of QK, QB, QC, AB, AC, BB, BC, ~~to 20~~ 20 and DQ to (20, 4)

replace VATP by ATZ(202, 20) BTZ(203, 20)

replace VAZ, VBZ, VAT, VBT by VAP, VBP (202)

(Result was into 5th bank.)

12/10/63 WXR 781C

Reorganized main program somewhat

Statements 120 – 244 take care of input
250 – 254 JS, JH, JT, NLZ, NZ
260 – 282 TK and ZJ
311 – 332 NSTEP ⟶ DELSIX
350 KT=1 for loop to 500
360 – 370 set up initial values
410 – 4250 NABC to control print VAZ etc.
430 – 450 form VATZ(KT, JZ), VBTZ(KT, JZ)
480 if $KT < NT$ compute, otherwise go to 520
491 – 510 IFAB ⟶ 81C & 82C
520 KN=0 to control branching at 662
for intracellular & two extracellular sets
532 – 550 Print VATZ & VBTZ
560 – 569 plots versus Z
570 – 650 plots versus T
660 advance KN by 1
662 go to (700, 750, 800), KN
700 – 727 → 532 Takes care of VE for zero shunt
750 – 783 → 532 " " " " for 0.25 factor
800 look for new input cards

Also introduced A(JZ)**3. into 81C & 82C
This caused log error
(presumably sought log of zero)

See next page

12/12/63 81C & 82C apparently had trouble from very large negative exponents. To take care of this & also save computation time replace old 465–467 with following

81C

```
454 DO 468 JZ=1,NZ
455 ATEST=A(JZ)-.001
456 IF(ATEST) 457,457,464
457 ASQ=0.
458 ACUBE=0.
459 BTEST=B(JZ)-.0001
460 IF(BTEST) 461,461,466
461 DB(JZ,JR)=-B(JZ)*ROUTB
462 DC(JZ,JR)=-C(JZ)*ROUTC
463 GO TO 468
466 DB(JZ,JR)=RINB*ACUBE - etc.
467 DC(JZ,JR) = as before ... ending with ASQ
468 CONTINUE
```

82C JZ=1,JS

```
464 ASQ=A(JZ)*A(JZ)
465 ACUBE=ASQ*A(JZ)
```

Also, correct 81C at 728 & 730 to provide for axonal core resistance being larger than combined dendritic core resistance. See p. 30 of these notes

This is correct, but goofed →
in program by using JZ instead
of NZ as index in part of (452)
* not discovered until 12/20/63

12/13/63 WXR781C with 81C & 82C

quite a few minor errors still had to be worked thru.

~~[illegible]~~ The Ax–Soma–Dend sequence was not yet completely correct in 82C

Also, to provide for synaptic excitation & inhibition in 82C

452 $$DQ(NZ,JR) = \begin{cases} CD*(A(NLZ)-A(NZ))-A(NZ) \\ +B(NZ)-A(NZ)*(B(NZ)+C(NZ)) \end{cases}$$

here $B \equiv E$ and $C \equiv J$

also for $JZ = JT, NLZ$

also $DB + DC = 0.$ for $JZ = JT, NZ$

(Not finally correct until WXR 84C)

Replaced HAFQCH with QENCHB

The input control of B & C in dendrites of 84C was finally introduced into WXR783C

Basic format for text prints is

upto 8X, 14(1X, F7.4)

$\boxed{14 \times 8 = 112}$

12/14/63 – 12/15/63 worked Sunday & keypunch 38

WXR 783C with 83C & 84C

Changed NZ dimension to (14)

Revised some formats

Card 1 now has NT, NSTEP, DT together also (NEJ)

Card 2 changed KDZPLT to LJZPLT
KDTPLZ to LKTPLZ

and compute MDZPLT
MKTPLT

Card 3 → put NJA, NJD together, delete NSTEP here

Card 4 replace VIZ with VAZ

Card 5 unchanged (QENCHA, QENCHB)

IF(NEJ) read KEJ, KTA(KEJ), KTB(KEJ)
and (BEB(JZ,KEJ), JZ = JT, NZ)
(BJC(JZ, KEJ), JZ = JT, NZ)
for synoptic E & J values

Get rid of ACUBE, replace with ASQ
add KT to 83C & 84C arguments & test print

12/16/63

Test 63781.0004 } did not work because
63781.0005 } DT = 0.1 when
intended .01

IFAB = -1

redo these as 63781.0014 } as final test
63781.0015 } of ACUBE
troubles

These worked, proving that cube will work. Get faster spike.

↑ see p. 38

If finally wish to restore ACUBE to
later program, create 85C + 86C
but wait & see

Perhaps write special 721C to test
out squares, cubes, etc. with
additional constants

Extracellular calc could have
an option providing for radial
symmetry term. effect of r^2 on Vex

Use different r value for Intloc

12/16/63

63781.0014 IFAB = -1, 81C as on p. 36

RACT=600. RINB=30. RINC=10.
QuenchA=40. ROUTB=15. ROUTC=2. QuenchB=30.

Peak in ① at KT=9 TK=0.08 Avg. .96397
Peak in ② 20 TK=0.19 .95506

		KT=9.5		KT=19.5
in ①	VAZ=.964	.9656	②	.95596
	QB=.5167	.5949		.5702
	QC=.1509	.2104		.1968

Peak QB is .7478 for VAZ=.944

Peak QC is 2.967 for VAZ=.203
QB=.023

63781.0014
RACT=500. RINB=15. RINC=10.
QuenchA=40. RoutB=15. Routc=2. QuenchB=30.

① peaked KT=9, TK=0.08
VAZ=.93035
QB=.31714
QC=.17837

② KT=24, TK=.23
VAZ=.89727
QB=.29223
QC=.20713

③ KT=37, TK=.36
VAZ=.9024
QB=.3186
QC=.2519

④ KT=50, TK=.49
VAZ=.89695
QB=.32267
QC=.27758

63781 cubed version

.0014 DT=.01, NSTEP=2

∴DELT=.005

.0021 DT=.02, NSTEP=2

DELT=.01

12/17/63

IFAB = -1

Although 63781.0014 & .0015 worked well, for insufficient NT

63781.0021 failed, possibly because DELT was twice as large (DT doubled with NSTEP same)

Also, reduced Quench values may have contributed.

Note that revised 82C was used here. However troubles occurred in both 81 & 82 at same point, KT > 9, where things had been OK in .0014 & .0015

IFTEST = 12

Prepare 63781.0024 with NT = 181, DT = .01 & otherwise like .0014

WXR 783C modified to take care of NSP.

Number of antidromic spikes after initial condition. To permit interactions of antidromic with synaptic, for different timing.

At 140
2461 et seq.
370
390 et seq.

→ ASQ relation

spike latency ≈ .17 for first
≈ .12 for rest

~~ASQ method with 63:~~

spike latency ≈ .09 to .1 all day
except at JH to JS
there doubled

12/20/63
error
discovered
in 452
of B subrout.

12/18/63

63783.0001 ran but was stopped by operator.
Seemed to be OK., but there are in fact
errors to be corrected.

Ⓐ at 206 & 206 NZ not available
e.g. MJZPLT probably incorrect

Ⓑ 728 & 729 need to have PA & PB added, resp.
(The gradient is to be reduced by factor CORE, but not
the potential itself) This revealed by 63781.0024

When modify can rename 784, but first test out 785
Note: 783, 83 & 84 have ASQ but not ACUBE

785, 85 & 86 will have ACUBE because
of success of 81 & 82 with 781 in 63781.0024

63781.0024 ran very well with spike latency ≈ .1

VBTZ shows erroneous values creeping
into JZ = NZ = 10 cpt. as calc.
progresses.

Error revealed at 728 & 729
Also, decided to make minor changes
to scale from VMIN = -.225 to VMAX = +.225
also change -3. to -2.5
and change -0.25 to -0.2

12/19/63 – 12/20/63

Still troubleshooting WXR785C

fixed statements 206, 714
rearranged { 370–377
390–396

Also in WXR85C & 86C

changed IF(KRTEST)

& in main program, arranged that
KRTEST = 0 unless IFTEST > 80

Then NRKABC = IFTEST – 80

KNRK = 1, ~~Then +~~
later KNRK + NRKABC

KRTEST = 1 only when KT = KNRK

Discovered error in statement 452 of 86C

index was JZ where it should have been NZ

12/20/63
Trouble with formats 926 & 927 at 532
deficiency of input output package.
Can be fixed with comma after 2X,)

See block later by making
GSA smaller
GSD larger

Also, may want to raise threshold $\left\{\begin{array}{l}\text{decrease RINB}\\ \text{or}\\ \text{increase ROUTB}\end{array}\right.$

12/21/63 — 12/24/63

WXR785C now working, but 5 minutes is not enough to complete all of these problems

63785.0001 NT=6, IFTEST=81

Successful print within subroutines

.0002 NT=121, IFTEST=20

Really same as 63781.0024
except that now VBZ & VBTZ are not disturbed erroneous non-zero values for JZ=NZ because 86C fixed.

Operator stopped this before VE calc. was reached.

63785.0012 same with NT=101, IFTEST=0

x 300sec running time did not get to end.
operator stopped at JZ=4 with KVE=1

Seems to have been O.K. plot up to this point.

Get antidromic propagation 1, 2, 3, 4
get delay because of GSA<GA at 5

→ Also, see an A→B slope change.

Also in 6 get striking difference between active & passive dendrites.

12/24/63 63785.0003 NT=6 IFTEST=810

.0004 NT=121 0

Here testing orthodromic direction.

Case A has VAZ(10) = 0.3 initially

Case B has VBZ(10) = 0.3 "

and BEB = 2. for KT=1 to 51

Trouble in reading BEB was due to fact that JT & NZ were not yet defined in program. Worked on .0004 because JT & NZ carried over.

12/25/63 This day added clock reading feature to program.

WXR786C with 81C for plotting

WXR785C with 80C for plotting

12/26/63 63785.0012

complete & successful run.
for A+B antidromic

Further questions

① effect of slower falling spike

② Introduce $E_j = -0.1$

③ effect of higher threshold
(try increasing ROUTB)

④ may wish to provide for plotting interval different from tabulation interval

12/27/63

To save computation time, it may be worth considering a revised program ~~in~~ which the plot subroutine does not have VA, KA, VB, KB, and receives LA and LB from main program.

(248, 249)
Main program sets VMIN=0, VMAX=100.

and at 563 LA(JZ) = 100. * VATZ(KT,JZ) +1.5
564 LB(JZ) = 100. * VBTZ(KT,JZ) +1.5
567 change argument
also 620 & 630 & 640

702 2.5
703 VMIN -2.5
708 replace -2.5 with -.5
which will later be mult. by 100

*Note (This idea is perfectly OK. but may not save much time because the actual printing seems to set the time limit)

This further confirmed 1/15/64
even with improved 82C & "Buffering"

12/27/63

63786.0021 first run with clock.

(plot subroutine neglected here)

Learned

① Input setup takes less than 1 sec

② (33 secs) compute A only for NT=81, NSTEP=2
NZ=12, NTZSTP=1944

③ 5 or 6 plot calls without subrt. ≈ 1/5 sec each

④ To display VATZ (12×81) took 13 secs

⑤ Zero slant, again calc plus VATZ display " "

This suggests that printing takes much more time than computing.

This was also found to be true for plotting with the next test.

check this for spike which generates an afterpos. →

12/28/63

63786.0022 actually run with 785 C
with 80 C
because 81C not yet available.

*

GA	GD	GSA	GSD	Core	NJA	NJD
8.	32.	1.	64.	.02	3	8

Propagation velocity faster than before, as expected from larger GA .07 per Axonal seg

Axon soma delay very large .33 i.e. nearly 5 times

in dendrites .03 average

Interesting That soma spike later for case B Than for case A. Presumably because so near threshold. Can see A-B step which could be accentuated be ~~decreasing~~ increasing thresh by decreasing ROUTB

Next try RoutB = 30

Each plot (NT=91) took 12 to 13 secs.

---

* Finite shunt conductance gives ~~interesting~~ VE. esp. initial pos. in dendritic region

Note That case B has ~~no~~ surface neg.

12/28/63

63785.0006

useful orthodromic result, although here the G_E was erroneously left on too long.

Made two goofs not picked up until 1/7/64, 1/8/64

1/7/64 ATEST was incorrect in use of ABSF

1/8/64 Basic trouble due to erroneous use of QUENCH in CALL argument. should be QENCHA in Call argument but QUENCH in Subroutine argument.

12/31/63 Modify Several programs

Add AFPOS to 83C ✓, 84C ✓, 85C ✓, 86C ✓

Add EQJ 84C ✓ 86C ✓

Should Add AFPOS ✓ to 785C ✓ 786C 784C

Revise 81C & change arg?

Change VMIN & VMAX in 785C ✓, 786C 784C

* * *

New 81C will match new 784C & 786C

replace in main program see p. 46 LAP & LBP for VAP & VBP

replace NGRID with ~~NDPPL~~ NSKIP

in 81C get rid of calc of LA(KT) & LB(KT)
also KA & KB

SORD (111)

1/2/64

set up $\boxed{64785.0007}$ [redacted]

in view of 63785.0006, here KTB = 25 instead of 50

Also ROUTB = 30. & AFPOS = .10

set up 64785.0023

in view of 63786.0022, here NT = 51
NSTEP = 3
DT = .02

also ROUTB = 30. & AFPOS = .10

p.50

Trouble until 1/8/64 because Call Arg for 85C & 86C had QUENCH when it should have had QENCHA. QUENCH incorrect for subroutine argument.

adopted 1/9/64 in WXR85C, deferred WXR86C until 1/14/64

Tentative conclusion

remove ABSF entirely at 485

also 466 BTOC = QENCHB * B(JZ) * C(JZ) + ROUTB * B(JZ)

4661 DB (JZ, JR) = RINB * ACUBE ~~- ROUTB * B(JZ)~~

- BTOC

467 DC(JZ, JR) = BTOC - ROUTC * C(JZ)

in other words RINC would not be used.

DC = (10.)(0) - (2.)(1.) + (40.)(1.)(.01)

= 0 - 2. + .4

Suppose A = 1., B = .8, C = .5

then DB = 30. - (20.)(.8) - (30.)(.8)(.5)

= 30. - 16. - 12. = +.2

& DC = (10.)(.8) - (2.)(.5) + (40.)(.5)(1.)

= 8. - 1. + 20.

1/8/64

64785.0031 first result after fixing QENCHA in Arg.

learned that after pos. lasts too long.

\# True cause of this trouble not found and corrected until 1/21/64 see (p 61)

value of B goes neg.

value of C lasts too long.

Assess what to do.

C can be brought down sooner with larger ROUTC

Study at statement 455 of WXR85C (1/7/64) version

```
455 ATEST = ABSF(A(JZ)) -.001
456 IF(ATEST) 457,457,464
```

No problem as long as A(JZ) ≥ ~~0~~.001
but for A(JZ) < -.001
we go to 464 ASQ is pos, ACUBE is neg.
~~466 DB~~

suppose A(JZ) = -.1, B=0, C = 1
RINB = 30., ROUTB = 20., QENCHB = 30.

Then DB = (30.)(-.001) - (20.)(0) - (30.)(0)(1.) = -.03
if B = -.0005 get
-.03 + .01 + .015 = -.005
∴ Should have ACUBE = 0

64785.0032B

This may correspond to the progressive inactivation bursts of Spencer & Kandel & others, as pointed out to me by Gordon.

For normal spike expect that need to increase SQENCHB &/or ROUTB
& decrease ROUTC

1/10/64

64785.0031 with ROUTC = 2. & ABSF was pinned to afterpot.

64785.0032A 10. but still showed two interesting features

I - system is now underdamped (cpts 2 & 3 were starting to oscillate)

i.e. increased ROUTC shortened rel. refract. period too much

II - also in cpt. (1) got active afterpos. growth due to ACUBE neg making B grow neg.

This is definitely unphysiological

\# ∴ revised 86C to delete ABSF, believe that this should now prevent or at least greatly limit neg values of B

Infact BTOC apparently was too weak & ROUTC was too large, such that VAZ & AB began to climb again when spike had fallen only halfway

1/10/64 Did this Today 78C 82C

Note for future mod. of program

change PRANGE to 110./

& DSCALB to /11.

as in 1/6/64 version of 81C

but have VA + VB instead of LA + LB in arg.

Call this 82C (Blend of 80C & 81C)

& calc JA & JB directly from VAP + VBP

at 200 & 201

Thus each calc is done between each printer line - Should save time, especially with buffer.

Need to change NGRID to NSKIP in arguments & in main program input format

Note soma spike exceed 1.0
and was only one to do so.

* It is also interesting that the axon-soma delay results in building the value of C up much longer in the soma than anywhere else. This should give larger afterpos. Also, more cumulative, as has often been observed. This will also give AB, A-2, I would guess.

TK=.1

TK=.2

TK=.3

TK=.6

Better reduce value of AFPOS

1/10/64 Compare 64785.0033, 34, 35

.0033 had	ROUTB = 20.	ROUTC = 2.	QENCHB = 40.
34	30.	"	"
35	"	5.	"
36	"	10.	"

First Compare in Compartment ①

.0037	"	10.	60.
.0038		5.	60.

.0033	.0037	.0034	.0038	.0035	.0036
.9392	.9179	.9156	.9123	.9189	.9237
.5318	.3654	.3764	.3559	.3817	.3876
.3467	.2903	.3157	.3151	.2997	.2763
.2096	.4569	.2483	.2454	.3817	.5777
.0174	.0455	.0194	.0117	.0422	.1023
1.7997	.9829	1.5997	1.1901	1.4007	1.1705
-.0780	.1794	-.0693	-.0387	-.0281	.3539
.0000	.0048	.0000	.0000	.0000	.0266
1.4895	.4298	1.3288	.7324	.8915	.6168

-.0972	-.0048	-.0967	-.0824	-.0837	.459
.0000	.0000	.0000	.0000	.0000	.051
.8174	.0223	.7293	.1634	.1989	.808

electrotonic spread back
from soma to axon
exceeds axonal threshold

These effects were at least partly due to
error not corrected until p. 61

1/14/64 summary as of

Run 64785.0036 (underquenched) & underdamped

ROUTB = 30.
QENCHB = 40.
ROUTC = 10.

In this case, second spike developed when first spike had fallen to 0.34

Due to underquench & underdamp

Run 64786.0037 QENCHB increased to 60.

in this case, only soma starts up again on its own bat.

presumably soma does because ROUTC was too large.

Here, second spikes in ③, ② & ① are clearly ~~as~~ secondary orthodromic propagation

---

Run 64786.0038 ROUTC reduced to 5.
QENCHB kept at 60.
ROUTB still at 30.

Here soma second spike has been prevented by the smaller ROUTC.

* → Also secondary orthodromic is present but considerably delayed & rather subnormal

1/14/64

64786.0101 had NSP=1 , KSP=31

ROUTC = 5.
QBNCHB = 60.
ROUTB = 40.

RMB=20.
compared with previous 30.
this slows devel of spike
considerably
(previously raised thresh)
but does not change prop. velocity
much

Got secondary
orthodromic again

64786.0102 KSP = 61
ROUTC = 3.
AFPOS = .05

This seems to have blocked the secondary
antidromic
• However, get peculiarly
large neg. values at end.

See p. 61

Require further analysis

SPK did not ~~add much~~ grow in ①
very poor in ②
peaked 0.34 in ③ at NT = 85
presumably helped by Soma spike

1/15/64

from p. 33 $GD = \frac{gd}{Cd} = GDS$

$GA = ga/C_a = GAS$

$GSD = gd/C_s$

$GSA = ga/C_s$

$GSA = \frac{1}{8} GA$ implies that $C_s = 8 C_a$

$GSD = (2.) GD$ implies that $C_s = \frac{1}{2} C_D$

~~at~~ so that $C_D = 16 C_a$

See p. 61

Was begining to suspect that trouble is caused by GSD = 64., but this was OK earlier in problem 63786.0022 on 12/28/63

However, since Axonsoma delay is a bit long, consider

GA = 8., GD = 16., GSA = 2., GSD = 32.

At that time there was no trouble with oscillation.

ROUT = 2. C value rose to over 2. as spike fell.

1/15/64

examine cpt. ④ of 64786.0102 at KT = 141

A = −.105   A(3) = −.0611 , A(5) = −.0776
B = 0
C = .2661 & has been falling

in WXR85C at ~~statement~~ 453

see p. 61

erroneous

DQ(JS) = GSD*A(5) + GSA*A(3) − A(4)*(1.+GA+GO)
+ RACT*B(4)*(1.−A(4)) − QUENCH*C(4)*(A(4)+AFPOS)

Here get (64.)(−.0776) + (1.)(−.0611) − (−.105)(41.)
+ (600.)(0)(1.+.105) − (40.)(.266)(−.105+.05)
−.055

= −4.96 − .0611 + 4.3 + 0 + .585

= −5.02 + 4.88 = −.14 hence more neg.

However, if C were larger, say 4 times as large,
then would get −5.02 + 5.7 ≅ +.7

Now, at KT = 85, C was 1.36 & then decayed

Once B hits zero, C is no longer fed.

Must consider smaller AFPOS & smaller ROUTC plan to rerun without second spike as .112, .113, .114 with NSTEP = 4

added 1/22/64

	GA	GD	GSA	GSD	G_{SS} WAS	Should have be
102	8	32	1	64	41	66
103	8	32	1	32	41	34
104	8	32	1	64	41	66

1/16/64

Comparison of 64786.0102
.0103
.0104

is very interesting, but very puzzling in some respects.

I Why should some spikes be blocked in 103 ?
! It differs from 104 only in GSD=32
o instead of 64.
see p. 61

II Still not clear why neg phase grows
! in 102. There is something wrong
o here. AFPOS should not grow.

Control on this provided by 104, where AFPOS was zero.

One clue May need NSTEP=4

because trouble in 102 seems to be related to GSD=64. & passive electrotonic term related to it. This may be a step size error.

This was tried but made negligible change

NSTEP=4

did not help

Runge Kutta
Computing time

for 9 pts Approx 23 sec per 100(NT)*2(NSTEP)
or 12 sec per 100 NT*NSTEP

1/17/64

Increase of KT dimension to 251
took memory map into bank 7

Also IFTEST=510812 worked for 64786.0203

(No Second Spike)

64786.0112 is identical with 64786.0102
except for increase of NSTEP from 2 to 4
(No second spike) & IFTEST from 12 to 15

Compare VATZ tables first.

Spike propogation was identical

Also, incl. ⑨ + ④,⑤,⑥,⑦,⑧ which was not affected by second spike, the neg values more neg than -.05 are the same as before.

∴ Not due to step size

∴ still get undesirable neg. growth for .0112

Comparison is useful for getting effect of second spike.

IFTEST=0 for 64786.0111

89 secs for 201 VA + 201 VB
NT

~~89 approx 23 secs for 100~~
NSTEP=22

Delay = 53-33 = 20 KT here

previously got 75-33 = 42KT

1/17/64 64786.0111

differs from 102 & 112 in Geometry & ROUTC = 2.

GSA/GA = 40/8 GSD/GD = 320/16.

as expected, this shortens axon soma delay

also, trouble with negativity is less severe, but still present.

Also, here, got both cases, A&B.

Case A neg grew to −.093 in ④ & was still growing

Case B much less, mainly because of the passive dendrites.

biggest neg occurred in ①

1/17/64

64786.0203 validated Spot Runge Kutta
also validated inhibition set up

Best seen comparing compartment ⑤ of
202 & 203

peak in ⑤ .497 .3985

at KF=75 & KT=75

To block, inhib would have to occur earlier.
Say around KF=41

in future use UA for μA. Previously used GA

Define $\mu A = \frac{GA}{CA}$ $\mu D = \frac{GD}{CD}$

Then $\frac{\mu D}{\mu A} = \frac{GD}{GA} * \frac{CA}{CD}$

N = number of dendrites

$$= \left[N\left(\frac{DD}{DA}\right)^2\left(\frac{LA}{LD}\right)\right] * \left[\frac{LA}{N \cdot LD}\left(\frac{DA}{DD}\right)\right]$$

$$= \left(\frac{DD}{DA}\right)\left(\frac{LA}{LD}\right)^2$$

$$= \left(\frac{\Delta ZA/\partial A}{\Delta ZD/\partial D}\right)^2 = \left(\frac{\Delta ZA}{\Delta ZD}\right)^2$$

For convenience, could let LA = LD

Then $\boxed{\frac{\mu D}{\mu A} = \frac{DD}{DA}}$

But $\frac{CD}{CA} = N\left(\frac{DD}{DA}\right)$

and $\frac{GD}{GA} = N\left(\frac{DD}{DA}\right)^2 = \frac{\mu SD}{\mu SA}$

Suppose $\frac{DD}{DA} = 4$ and $N = 5$ then $\frac{\mu D}{\mu A} = 4$

$\frac{CD}{CA} = 20$

Suppose $\frac{CS}{CA} = \overset{10}{4}$, Then $\frac{CD}{CS} = \overset{2}{5}$

$\frac{GD}{GA} = 80 = \frac{\mu SD}{\mu SA}$

Then $\frac{\mu SA}{\mu A} = \frac{1}{4}$, Then $\frac{\mu SD}{\mu D} = 5$

EG. $\mu A = \overset{10}{8}$, $\mu D = \overset{40}{64}$, $\mu SA = \overset{1}{2}$, $\mu SD = \overset{80}{320}$

1/21/64

Finally discovered error in the Diff. Equations of Runge Kutta

Statement 453 of subroutines was

```
DQ(JS,JR) = GSD*A(JT) + GSA*A(JH)
        - A(JS)*(1. +GA +GD     error
        + RACT*B(JS)*(1-A(JS))
        - QUENCH*C(JS)*(A(JS)+AFPOS) )
```

whereas should have been

```
   GSD*(A(JT)-A(JS))
 +GSA*(A(JH)-A(JS))   -A(JS)
 +RACT . . . .
 -QUENCH . . . .
```

Because GSA+GSD corresp to μ (not λ) and depend upon capacity of soma.

Error meant that μ_{ss} was incorrect

E.G.

GA	GD	GSA	GSD	incorrect μ_{ss}	correct μ_{ss}
8	32	1	64	41	66
8	32	1	32	41	34
8	16	4	32	25	37

In program better change GA to UA etc.

1/21/64

from previous page, for LA=LD

Here $\frac{\mu D}{\mu A} = k$ $k = \frac{DD}{DA}$

$\frac{\mu SD}{\mu SA} = \frac{GD}{GA} = k^2 N = 5k^2$ for N=5

Thus, for $k = \frac{DD}{DA} = 4$
$N = 5$

get constraint
$$\boxed{\begin{aligned} \frac{\mu D}{\mu A} &= 4 \\ \frac{\mu SD}{\mu SA} &= 16 * 5 = 80 \end{aligned}}$$

For $\mu A = 10.$ & $\mu D = 40.$

can have following pairs

$\mu SA = 1$ with $\mu SD = 80$

or $\mu SA = 2$ with $\mu SD = 160$

or $\mu SA = 4$ with $\mu SD = 320$

or $\mu SA = 8$ with $\mu SD = 640$
10 800

or $\mu SA = 0.5$ with $\mu SD = 40$

64791.0111 A neglected 91C & 92C

Hence get format time compared with computation time

	64791.0111A		64791.0111B	
Setup — elapsed time	2 sec		1 sec	
		28		123
test printing IFTEST=15 NT=201 IFAB=0 (7 pages of test print approx 36 lines per page)	30sec		124	
		41		50
404 lines VATZ, VBTZ	71sec		174	
		14		14
206 lines plot JZ=1	85		188	
		15		15
" 2	100		203	
		14		14
" 3	114		217	
		15		15
" 4	129		232	
		14		14
" 5	143		246	
		15		15
" 6	158		261	

Get about 10 lines of printed output for 1 sec (test print VATZ, VBTZ)

Get about 15 lines of plot graph output for 1 sec

Actual Runge Kutta computation added 100sec for Cases A+B NTSTEP=402

1/21/64 – 1/22/64

WXR791C
WXR91C
WXR92C
WXR82C

64791.0111

Crucial error in DQ(JS) now corrected

This will be beginning of new series.

64791.0111 revealed several interesting points

① No longer have trouble with growing negativity. Presumably can now increase ROUTC again, perhaps to a value of 3, 4 or 5.

② Got Soma block for $\frac{GSA}{GA} = \frac{4.}{8.}$, $\frac{GSD}{GD} = \frac{32.}{16.}$

Presumably need to increase RINB and/or decrease ROUTB

③ Falling phase of spike looks good. Presumably because RENCHA = 20. which was smaller than in all previous runs on 786C where value was 40.

④ Spike in cpt ③ (hilloc) falls more sharply & has less afterpot, than ① or ② because it receives much less back-spread from next cpt.

Also note that some amount of Runge Kutta with IFTEST = 0 took 139 secs in 64786.0111 / may depend upon location of subrt. on program tape

In 64791.0111B

look at cpt ④ (same) peak when KT = 41

A = .1545
B = .0016
C = .0037

reverse case differs little

probably not far from threshold

whereas ② when KT = 11 had A = .1705
B = .0012
C = .0010

16 (near peak in ①) A = .3722
B = .0117
C = .0097

set up 64791.0211 with ROUTB reduced to 20.
also ROUTC raised to 3.

also set up 64791.0312 with above plus RINB = 30.
& .0313 which was regular value
before 64786.0039

1/22/64 comparisons

	UA	UD	USA	USD	Uss	$\frac{U_{ss}}{USA}$
64791.0111B	8.	16.	4.	32.	37.	9.25
.0112	8.	32.	1.	64.	66.	66
.0113	8.	32.	1.	32.	34.	34

all three have same Card 5

RACT = 600., RINB = 20., QENCHA = 20.

ROUTB = 40., ROUTC = 2., QENCHB = 60., AFPOS = .05

all three block at soma

" " have peak in ① of .8969±1 at KT = 17

" " " " " ② .8926±3 at KT = 24

~~" " " " " ③~~

.0111 has peak in ③ of .8678 at KT = 33 when V(4) = .1172
41 .1545

.0112 " .8600 " .0222
39 .0273

.0113 " .8612 " .0341
40,41 .0453

Which agrees with intuitive notion that the dendrites offer the largest ~~cond~~ input conductance load to soma in .0112 (See p. 62) $\frac{USD}{USA} = 64.$

next largest GD in .0113 32.

least GD in .0111 8.

peak values in ④ are ~~∞~~ $\frac{USA}{USD}$

How close to threshold was .0111? see left page

1/22/64

Just got idea for a stochastic model of neuronal branch pattern. Could be used to explore (Monte Carlo fashion) the effects of different directional bias, different variances in branch lengths & bifurcation patterns.

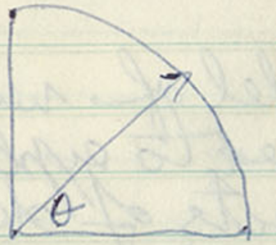
Also, & this is what led to this idea, it can be used to test to what extent larger branches & trees are more probably cut off than are short ones.

May need to use θ, ϕ, r & x, y, z, or possibly can get away with only one

Using x, y & z, the pattern in x & y only could be plotted to silhouette for different thickness of slice. This could all be done with machine plotting if properly planned.

This is method for getting a model of the distribution that is truncated. Probably tree could be of infinite extent & still sample would be extremely finite, for finite slice

Stochastic Model of Dendritic Branching Distributions consider probability related to sin θ



let $\theta = 45° = \frac{\pi}{4}$ be most probable

let $\theta = 0$ or $90°$ be zero probability

could ~~consider~~ $p \propto \sin(2\theta)$

But Farlow would use equal prob. & go through a dist.

1/23/64

66037

Talked with Jerry Farlow in J. Johnson's group
He has subroutines needed for Monte Carlo approach
He thought plan was feasible, but he is pretty busy. He thought there might be a subscripting problem, to specify branches. However, my solution is to note the following -

Each branch point will have four values attached to it

$$X(K)$$
$$Y(K)$$
$$Z(K)$$
$$IP(K)$$

where $IP \equiv$ index of parent
$=$ value of K for parent branch point.

Could let soma be a point.
Could specify mean & variance for each branch length
two parameters for branch orientation

First try both branches indep't of each other — specify θ by means of θ_m & σ_θ^2
let ϕ be uniform dist.

Set up some production runs

I Collect card with S in col. 8

II IFTEST = 0

III NPLT = 9

IV IFVE = 1 CORE varies

otherwise as before

.02111 let CORE be 0.1

.04111 = 0.05

.1413 0.05

.1513 0.05

Try .0612 with F.C. of .05 in the dendrites.
.0613 " " " ~ ~ ~ ~ ~

1/27/64 Prepared outline (see back of this book) summary of twelve latest problems 6479.0111 thru 6479.0513

Got complete soma block in .0111, .0112, .0312, .0412, .0512 .0113, .0313.

.0211 got soma spike at KT=62 for active dendrites & KT=80 for passive
The later soma spike reflected orthodromically while the earlier one did not. This represents a special set of circumstances

.0411 increased UD to 32. & USD to 64. Soma blocked in passive case
soma spike at KT=111 for active dendrites.
peripheral dendrites spiked slightly before soma.

.0511 proves that USD/USA the same gives same result.

.0413 soma spike at KT=82 for active dendrites
blocked for passive dendrites.

.0513 soma spike at KT=132

1/28/64

.0612 had residual tail as initial condition.
Soma spike at KT=35. No reflected spike (too early)

Best way to prevent reflected antidromic is to avoid long antidromic latency from Hilloc to Soma.

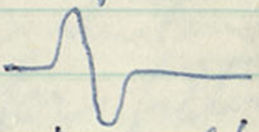
To help analysis of extracellular pots. note the KT values for spike peaks of intracellular records!

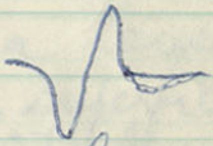
Cpts	①	②	③	Soma ④	
.1211	14	21	29	A63, B81	antidrom
	B113	B108	B97		orthodrom
.1411	14	21	29	A111	antidrom
	A136	A131	A121		orthodrom
.1413	9	14	20	A81	antidrom
	A107	A101	A93		orthodrom
.1513	8	14	19	A132	antidrom
	A151	A144	A139		orthodrom.

1/30/64

68

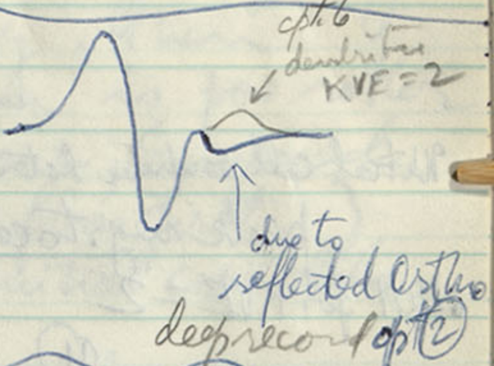
Looking over production output

.1411 soma extracellular was  (+, -)
because dendritic periphery fired before soma.

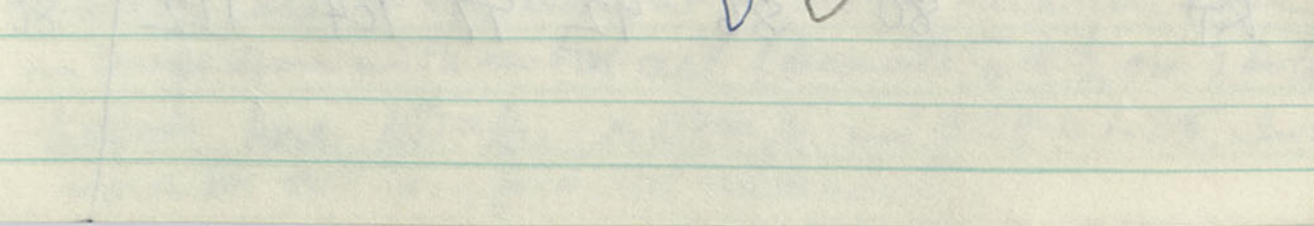
.1413 soma extracellular was 
(−, +, (−)) because soma fired before dendritic periphery & the small terminal neg. corresp. to the reflected orthodromic

.1513

dendritic periphery fires first.



.1211 Case A has good dendritic spike latencies



Mitral cell dendritic latency with distance ~ 1 msec/mm

peak neg. to cell body layer drops to ~1/2, at level halfway to glomerular layer

:1211 for KVE = 2

	neg peak						positive peak	
	④	⑤	⑥	⑦	⑧	⑨	⑧	⑨
active dendrites								
ampl	-1.82	-1.82	-1.73	-1.50	-.88	-.38	+.30	+.39
KT	62	63	66	70	73	81	61	62
passive dendrites								
ampl	-1.61	-.79	-.39	-.15	-.01	+.04	+.30	+.35
KT	80	86	92	97	104	112	80	80

1/30/64

Conclusions from study of Production Output.

Ⓐ Extracellular Pots. with external conductance path (ie. <u>KVE = 2</u>) are necessary for fitting mitral cell data because

Both passive & active cases convert the leading negativity seen near the soma level to a leading positivity at the superficial levels. This thus the case for mitral cells.

Ⓑ The anomalous computed results where, because of very long hillock-soma delays, we find dendritic periphery firing slightly before the soma (namely, then the leading potential at soma is pos. rather than neg i.e. ∿ +,- diphasic, (compared with -,+ diphasic when soma fires first))
This does not correspond to mitral cell data.

Therefore, should, for the present, seek sets of conditions which reduce hillock-to soma delay, such as, dendritic facilitation.

Ⓒ In problem 64791.1211 the extracellular amplitude decrements too much with distance for passive dendritic case & too little with active dendritic case in comparison with mitral cell (decrements to $x\frac{1}{2}$ over $\frac{1}{2}$ distance)
(see left)
however, here $lD = 16.$, $\therefore \Delta Z = 1/4$ and $5\Delta Z = 1.25$, which is probably too long for mitral cell dendrite.

69 1/30/64

Conclusions from Study of Inductor Output

(A) Extracellular Potassium with external conduction path (i.e. KVE = 2) are necessary for fitting mitral cell data records.

Both positive & active cases convert the leading negativity seen near the soma level to a leading positivity at the peripheral levels. This was the case for mitral cells.

(B) The analogous computed results where because of very long hillock - soma delay [illegible]

2/3/64

.0632B Rung Kutta test print of DQ(4)

Violent oscillations develop during

KT=20

try larger NSTEP

? machine error

Trouble probably due to USD = 160. being too large for step size.

1/31/64

Ⓒ continued. ∴ decide to rerun with $\mu D = 64.$
to correspond to total shorter L/λ.

Results from 64791.0631
Blocked at soma.

$\mu A = 16.$, $\mu D = 64.$
$\mu SA = 2.$, $\mu SD = 160.$

RACT	RINB	QENCHA	ROUTB	ROUTC	QENCAB	APPOS
600.	50.	20.	20.	3.	30.	.10

half of previous

twice previous

64791.0631 (above) blocked at soma.

64791.0632A differed only in I.C. = 0.1 in the dendritic compartments.

active case

Here, soma was invaded without delay.
In fact, entire dendritic system fired synchronously because 0.1 proved to be above threshold.

However, Computation blew up at KT = 21
Put in a rerun with IFTEST = 1902381

Passive case

got thru with delayed soma spike (KT = 68) which reflected orthodromically

Also, spread into dendrites was less decremental because of shorter Z length. as expected.

.0622 I.C. was .04 in soma & D.
active case soma spike at KT = 51
reflected ortho failed.

1/31/64

Backtrack to look at 64791.0612
613
712 A+B
621
622

In 612, first tried I.C. = .05 in soma & dendrites.
This was for 8. 32. 4. 128.
600. 50. 20. 20. 3. 60. .05

Same as .0512 except for the I.C.
which had blocked with soma peak = .054

active case invaded soma with only slight delay. KT=35
too soon to permit reflected ortho.

passive case blocked with soma peak = .0985

.0613 similarly related to .0513 8. 32. 8. 128.
IC = .05 in soma & dendrites.
active case soma spike at KT = 32 compared with 132 for .0513
too soon to permit reflected ortho.

passive case blocked with soma peak = .1486
compared with .1004 for .0513

.0712 B with second stimulus at KT=51
Did not grow full size & did not propogate because of refractory period.

.0621 10. 40. 2. 160. with IC = .05 in soma & D.
active case soma spike at KT = 38
too soon to permit reflected ortho.

2/3/64

Trouble presumably due to USD = 160.
Could also try with USA = 1, USD = 80.

sharp dendritic electrotonic view of spike
which decrements from 0.86 to 0.43
with a steady latency shift -

good looking spike

& 2/3/64

1/31/64 New series 64791.0631 et seq.

$\mu A = 16.$, $\mu D = 64.$, $\mu SA = 2.$, $\mu SD = 160.$

600. 50. 20. 20. 3. 30. .1

see p. 70 This blocked at soma for both active & passive dendrites

64791.0632 A I.C. = 0.1 in all dendritic cpts.
~~case~~ of active dendrites blew up KT=20-21
case of passive " late spike at KT=68
& reflected ortho! ampl .8545

64791.0632 B got same result with Runge Kutta print.
Need to retest with NSTEP = 4

64791.0633 I.C = .05 in all dendritic cpts.
active case blew up with soma spike at KT=42
passive case blocked.

64791.0634
by mistake
g=0.2 in ⑤
passive only. similar to .0632 ⑥⑦⑧⑨
but with E = 0.2 in dendrites.
from KT = 1 to 30
Got soma spike at KT = 46 ampl .8574
too early to produce reflected orthodromic

64791.0635 passive only ~~similar~~ I.C. & E J
altered kinetics
500. 30. ⑮ 20. 3. 40. .1

obtained a near steady state in soma
local response
which finally, by KT=100 was starting to take off

both of these slower kinetics
prevented blow up.

2/3/64

64791.0636 active case only
kinetics same as 635
Good looking spike, some spike at KT=29
Synchronous dendritic spike

64791.0637 active case only
same as .0632 except for QIAB=60.
This prevented blow up
Synchronous spike at KT=19

Plan new series

IFAB = -1

.0641 Same as .0632 with USA=1, USD=80.
.0642 " " " " . with NSTEP=4
.0643 same as .0633 1, 80.

.0644 like .0634 with Σ instead of J in ⑤
.0645 " .0635 " "

.0646 like .0636 except I.C. .02, .04, .06, .08, .1
.0647 like .0637 except.

.0648 same as above with reversed
.0649 dendritic sequence

WXR82C modification -

If JA − 110 is still pos, set JA = 110

If JA + 110 is still neg, set JA = 1

for all cases of JA & JB

WXR791C Mod. to set NT = KT if VAZ(JS) > 5.

Expect outcome of .0646 — .0649 production run will confirm this.

2/4/64

64791.0641 blow up was prevented by NSTEP = 4
Got synchronous soma dendritic spike.

.0642 got blow up inspite of USD = 80.

not sure why this did not happen with .0632 ? unless some change in software package

blow up caused very long time in plotting subroutine.
Modify WXR82C to prevent this in future

This was run a second time on 2/4/64 with same result. .0643 never was checked.

64791.0644 passive only good soma spike at KT=41
compare with .0634 (KT=46) which had J at (5)

64791.0645 passive only: delayed soma spike at KT=100
compare with .0635 st. state which had J at ⑤

It looks like hotter parameters should be used for the passive dendritic case, and cooler parameters should be used for the active dendritic case, to get suitable extracellular plots.

Authorizing Memo to Joseph P. Johnson 2/3/64

Preparing detailed memo 2/5/64

↓

Dittoed Memo dated 2/10/64

Met with Jerry Farlow & Betty Garber 2/14/64

On 3/9/64 their program seems to be working except for a bug in adapting to plotter.

2/14/64

refer back to p. 65 #66

Question of whether to doubly index (J, K)

J = order of branch point
K = index within that order

X(J, K)
Y(J, K)
Z(J, K)
KP(J, K) gives K value of parent whose J value is necessarily one less than here.

IFC(J, K, L) zero if not cut by plane for index L
1 if cut by plane for index L

XC(J, K, L)
YC(J, K, L)
ZC(J, K, L)
} coordinates of intersection of line to X(J, K), Y(J, K), Z(J, K) with plane for index L.

Dimension J = 10 $2^5 = 32$, $2^6 = 64$, $2^7 = 128$
K = rather large

---

alternatively NTRUNK = number of trunks
NORD = number of orders of branching

~~X(1)~~ K = 1 represents origin

NBR(1) = NTRUNK
KA(1) = 1 + 1 = 2
KM(1) = 1 + NBR(1)
NBR(2) = 2 * NBR(1)

→ KA(2) = KM(1) + 1
KM(2) = KA(2) + NBR(2)
etc to
KM(NORD)

2/4/64 for NTRUNK = 6

$$KM(NORD) = \overset{(1)}{1 + 6} + \overset{(2)}{12} + \overset{(3)}{24} + \overset{(4)}{48} + \overset{(5)}{96} + \overset{(6)}{192} \approx 400$$

for NTRUNK = 10, get $1 + 10 + 20 + 40 + 80 + 160 + 320 \approx 641$

for this case, dimension K ≈ 1000

need X(K)
Y(K)
Z(K)
KP(K)
IFCUT(K,L)
XCUT(K,L)
YCUT(K,L)
ZCUT(K,L)

optional KDA(K)
KDB(K) } daughters

L → ICUT

Calc. NBR(JORD)
KOA(JORD)
KOM(JORD)

~~KOA~~
~~NBR(1) = NTRUNK~~
~~DO JORD = 1, NORD~~

X(1) = 0.
Y(1) = 0.
Z(1) = 0.

NBR(1) = NTRUNK
KOA(1) = 2

KOM(1) = 1 + NTRUNK
~~NTBR = NTRUNK~~

DO J~~ORD~~ = 2, NORD
~~KOM(J) = KOA(J) + NBR(J)~~
KOA(J) = KOM(J-1) + 1
NBR(J) = 2*NBR(J-1)
KOM(J) = KOM(J-1) + NBR(J)
~~NTBR~~

Total number of branches & trunks = KOM(NORD) - 1

Try $USD = 64.$ $USA = \left(\frac{64.}{80.}\right) = .8$ ⟵

---

for active case try, $UA = 8$, $UD = 16$, $USA \begin{cases} 4. \\ 2. \\ 0.4 \\ 0.2 \end{cases}$ $USD \begin{cases} 320. \\ 160. \\ 32. \\ 16. \end{cases}$

for passive case try, try similar to .0644 ~~but with somewhat more E~~ or like .0647 with E made stronger

2/5/64 Thoughts on .0630-.0640 series

① If true geometry is as unfavorable as in current calculations, it seems that antidromic invasion must depend upon dendritic facilitation.

If so, then deep anesthesia should reduce the probability of invasion.

② So far nothing looks like an A spike, except possibly soma spike in .0645 passive dendrites, submax.

Maybe need higher kinetic threshold

Maybe need to juggle $\frac{USA}{UA}$ ratio

Conceivably need soma kinetics different from axonal kinetics, but reserve this for last.

③ For mitral cell extracellulars, it looks like the best passive dendrite case is with hot kinetics and a short dendritic tree, whereas best active dendritic case is with cooler kinetics and a longer dendritic tree. Need to compare the two best cases.

64791.0656 will be suitable for
a full scale run of
hot passive

64791.0657 not quite suitable for
full scale run of
cool active
because dendritic
periphery fires first

Then tried 64791.0658 with I.C. = .05
throughout dendrites & got too
long a delay.

Need to retry abortive 64791.0659 .1, .08, .06, .04,

also .0660 .08 in each

2/5/64 2 & 3 active dendrites

Prepare 64791.0651 NT=201 ~~NEJ=1~~ IFTEST=0

2 NPLT=2, LJZPLT=2, 1 1 IFHL=1, NPLZ=0

3 8. 16. 1. 80. - - -1

4, 5 & 6 like .0646 cool kinetics

.0652 same except USA=0.2, USD=16.

~~.0653 same as .0652 except that E values are doubled.~~

Prepare also 64791.0655 6 & 7 passive dendrites.

NEJ=1

Card 2 like above

Card 3 16. 64. 1. 80.

Card 4 ~~two~~ different I.C.

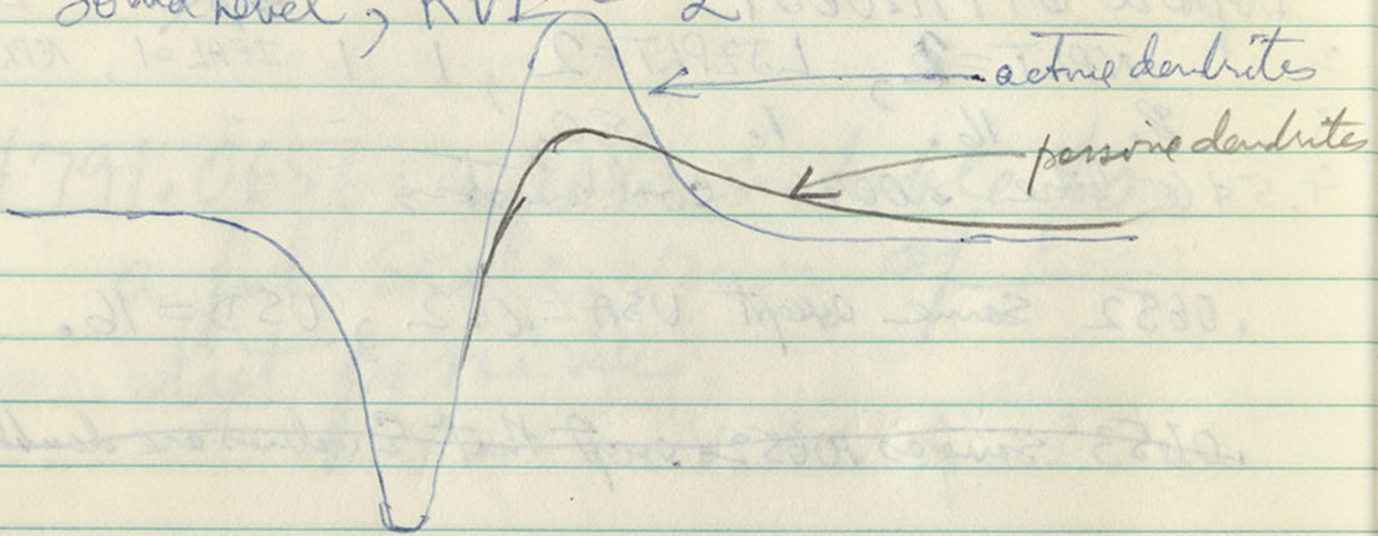
Card 5 hot kinetics

Card 6 two different E sets.

.02

JZ=4

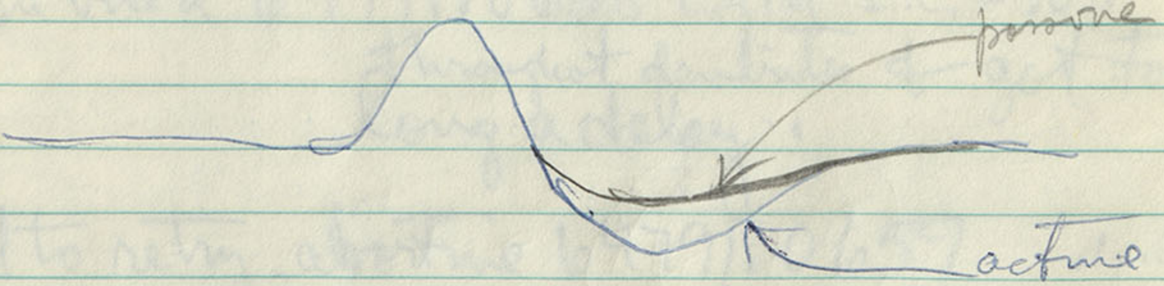
Soma Level, KVE = 2



by JZ = 6, both are shifted to right & attenuated - passive is more attenuated

These show most striking difference, but would be hard to test for this experimentally

by JZ = 9



peaks at JZ = 9 are reversed but at same times as those ~~of~~ JZ = 4

2/19/64 successful production runs

64791.0666 passive case (hot kinetics)

extracellular plot

(perfectly satisfactory as it was)

64791.0669 active case (cool kinetics)

extracellular plot

\# (too much soma delay
needs to be raised rerun for earlier
soma spike)

however much of it O.K.

Gordon thinks that both fit data equally well. Sometimes data more like one, sometimes more like other.

Both turnover their extracellular between soma level & peripheral level

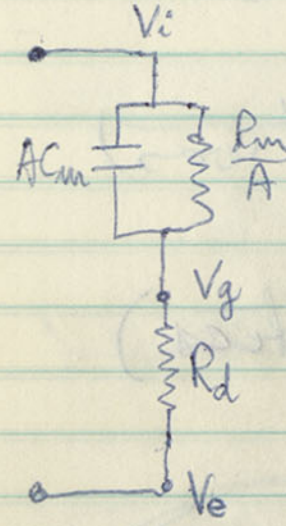
Essentially suitable for paper. Perhaps should get A+B in both cases?

Maybe program should have option of skipping the extracellular without shunting?

Complete paper will compare not only opt. A with option B, but also with partial A + partial B at least separately!

To add giant extracellular computation to program

On original dimple hypothesis



$$I_m = \frac{V_g - V_e}{R_d} = \frac{V_i - V_g}{R_m/A} + AC_m \frac{d}{dt}(V_i - V_g)$$

$$\frac{R_m}{AR_d}(V_g - V_e) = V_i - V_g + \tau \frac{d}{dt}(V_i - V_g)$$

(if $V_e = 0$) get $$\beta V_g + \tau \frac{dV_g}{dt} = V_i + \tau \frac{dV_i}{dt}$$

where $\beta = 1 + \frac{R_m}{AR_d}$

However, for $V_e \neq 0$ and not constant, get

get $$\beta(V_g - V_e) + \tau \frac{d(V_g - V_e)}{dt} = V_i - V_e + \tau \frac{d}{dt}(V_i - V_e)$$

β corresp to $\frac{1}{\alpha}$ of Fragkin & Frank's paper

$$\dot{z} + \beta z = \dot{y} + y$$

$$\dot{z} = \dot{y} + y - \beta z$$

Computation could be, for $\Delta t/\tau$

$$\Delta(V_g - V_e) \simeq \Delta(V_i - V_e) + \{V_i - V_e - \beta(V_g - V_e)\}\Delta t/\tau$$

Believe I will try this for $\beta = 2$ and $\beta = 10$

This will probably work, but Zim & Jose both pointed out that, if needed, a better method would be

convolution

$$z = z_0 e^{-\beta t} + e^{-\beta t} * (y + \dot{y})$$

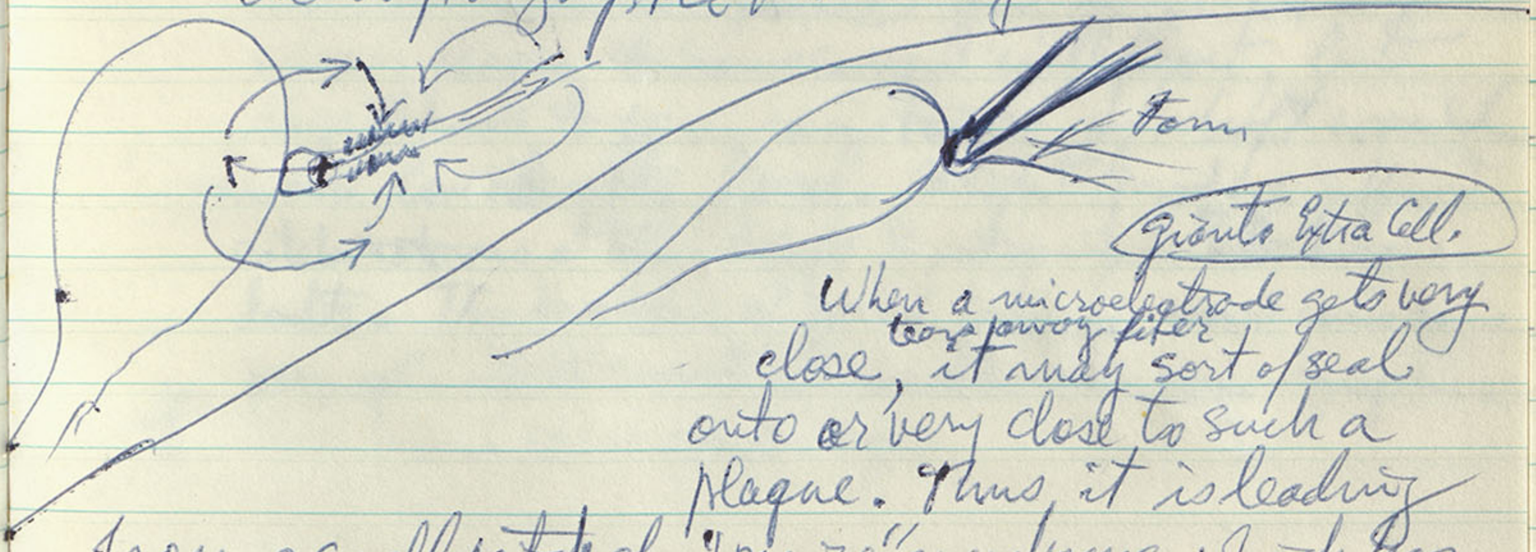
$$= (z_0 - y_0)e^{-\beta t} + y(t) + (1 - \beta)e^{-\beta t} * y$$

which has the merit of getting rid of $\dot{y}$.

i.e use that $e^{-\beta t} * \dot{y} = y * (\frac{d}{dt} e^{-\beta t}) - y_0 e^{-\beta t}$

2/19/64 (night)

Got idea that both giant extracellular & a non-chemical epsp could be explained on the hypothesis of a permanently low resistant synaptic plaque. E.M. shows a plaque of very close approximation. This could conceivably be a locking together of membranes to "line up holes" and maintain an ~~ever~~present low resistance. When both pre & post. synaptic neurons are at rest, no current would flow thru this channel. However an afferent impulse approaches ending, it opens a low resistance path & creates a pot. drop across channel. The resulting current flow would cause the epsp depolarization. Irreversibility could well result from high core resistance of terminal stems plus low safety factor do to presynaptic branching.



When a microelectrode gets very close, torn away fiber it may sort of seal onto or very close to such a plaque. Thus, it is leading from a small patch of "passive" membrane which has a low (shunt) resistance, but possibly normal Cm. Thus, ~~[illegible]~~ high resistance to volume is less necessary than in the earlier explanation.

Mentioned to Gordon [illegible] 2/25/64
He thought that plaque is more often thought of as high resistant, but knew of no evidence, offhand, against idea here.

One test of idea is whether giant extracellulars are ever recorded at surfaces which have no knobs. Gordon mentioned some cases of neg. giant extracell in line with this. Was it crayfish, or Aplysia or goldfish

Study of chromatolytic cells might have value.

Study of miniature epsp might have value.

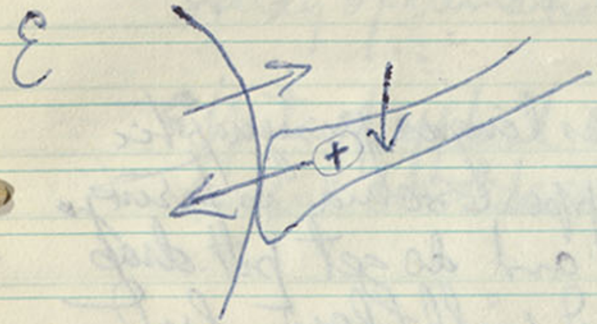
Effects of applied const. current require very careful consideration of geometry.

Further thoughts on this.
Key idea is low resistant plaque

What kind of test? If one cut off terminals, this should run the soma down. May be related to chromatolysis & shrunken dendrites. Suppose plaque were esp. permeable to K^+, then degen of knobs would result in K^+ loss & possibly to shrinkage, a la VanHarreveld & Marshall. Besides could conceivably be a K^+ storage (buffer).

Miniature epsp could be due to instability of individual terminals. Recheck Katz's paper. Does he have evidence for packets?

Note: plaque draws ~~no~~ current as long as presynaptic shaft has resting pot. Suppose soma is firing. Then soma interior goes ⊕ and do get pot. drop across plaque & some current will flow, but membrane & core resistance of shaft would make considerable load. Might produce sufficient catelectrotonus at terminal shaft to set up impulse? ~~but~~ have doubts. This is a crucial point because would cause some presynaptic refractoriness that would be non-homo-synaptic.
* This bears some pondering.


ε
+


−

Further thoughts.

Does this scheme have any implications for inhibition? Not necessarily, however.

(1) inhib. could result from sealing or plugging plaques
(2) inhib could result from blocking impulse upstream
(3) Can one juggle Equilib Pot. of plaque shunt?
(4) Inhib could be chemically induced J as before.

Suppose inhibitory presynaptic shaft differed from excitatory one by not having an impulse, but, instead, having only a high K conductance. In that case, the high K conductance of shaft in series with a high K conductance of plaque could act like a J patch. Only question would be how to get high K conductance in shaft? Is there any merit to idea of a block if afferent terminal branching is too profuse? In my impulse model, the aftermath of subthresh. stim can sometimes be persistent (C) – Check into this further. If this idea works, E endings could switch to J endings by a change in safety factor. This would have many interesting consequences.

for $h=4b$ and $x=b$ get $\frac{1}{2\sqrt{2}} + \frac{3}{2\sqrt{9+1}}$

$= \frac{\sqrt{2}}{4} + \frac{1.5\sqrt{10}}{10}$ $\frac{1}{1.208}$

$= 0.3535 + .4743 = .8278$

$x = h/6$; $h=12$, $x=2$, $b=3$

$\frac{\cancel{2}}{2\sqrt{4+9}} + \frac{10}{2\sqrt{100+9}}$

$= \frac{1}{\sqrt{13}} + \frac{5}{\sqrt{109}}$ $\frac{1}{1.323}$

$= .2770 + .479 = 0.756$

$x = b/2$; $h=8$, $x=1$, $b=2$ $\frac{1}{2\sqrt{1+4}} + \frac{7}{2\sqrt{49+4}}$

$= \frac{1}{2\sqrt{5}} + \frac{7}{2\sqrt{53}}$

$= \frac{1}{4.472} + \frac{3.5}{7.28}$ $\frac{1}{1.42}$

$= 0.224 + .480 = 0.704$

$x = h/12$; $h=12$, $x=1$, $b=3$ $\frac{1}{2\sqrt{1+9}} + \frac{11}{2\sqrt{121+9}}$

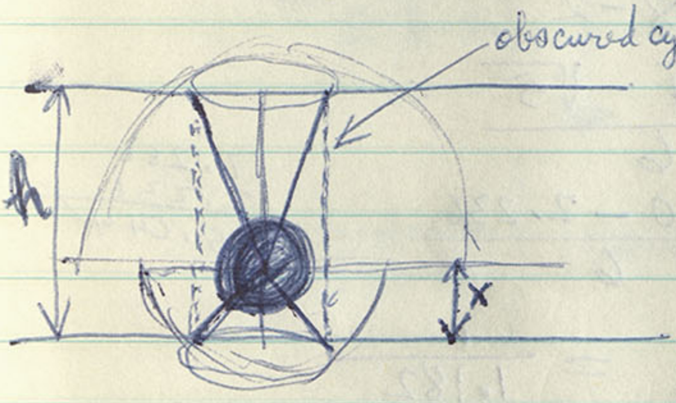
$= \frac{1}{2\sqrt{10}} + \frac{11}{2\sqrt{130}}$

$= \frac{1}{6.324} + \frac{5.5}{11.4}$ $\frac{1}{1.56}$

$= .1581 + .484 \approx 0.642$

2/20/64

In connection with revising paper on Aitken's data with help of Gordon, had occasion to work out an integrated average for the trunks lost or obscured by the soma.



b = true radius + ϵ
where ϵ length of unresolvable protuberance in silhouette, allowing also for trunk's ~~obscuring~~ shadows.

As long as center lies in the h range, we have from the Appendix of the two year old ditto, that the fraction seen can be expressed

$$f = \frac{x}{2\sqrt{x^2+b^2}} + \frac{(h-x)}{2\sqrt{(h-x)^2+b^2}}$$

Thus, for $x = 0$, get $f = 0 + \frac{h}{2\sqrt{h^2+b^2}} = \frac{0.5}{\sqrt{1+(b/h)^2}}$

suppose $b = \frac{h}{4}$, then get $\frac{0.5}{\sqrt{1.0625}} = 0.485$

While, for $x = h/2$, get $f = \frac{h/2}{\sqrt{(h/2)^2+b^2}} = \frac{1}{\sqrt{1+(2b/h)^2}}$

suppose $b = \frac{h}{4}$, then get $\frac{1}{\sqrt{1.25}} = 0.894$

Now, to average, we write $\bar{f}_{x_1,x_2} = \int_{x_1}^{x_2} f\,dx \Big/ (x_2-x_1)$

$x = b/2$ with ~~ε~~ $h = 4b$

get $$\frac{\sqrt{(8-1)^2+2^2} - \sqrt{1+2^2}}{8-2}$$

$$= \frac{\sqrt{49+4} - \sqrt{5}}{6}$$

$$= \frac{7.280 - 2.236}{6}$$

$$\begin{array}{r} 7.280 \\ 2.236 \\ \hline 5.044 \end{array}$$

$$= 0.84_6 = \frac{1}{1.182}$$

If soma is known to be uncut, then $X = b - \epsilon$

if $X = b$, get $$\frac{\sqrt{(h-b)^2+b^2} - \sqrt{b^2+b^2}}{h-2b}$$

and for $b = \frac{h}{4}$, get $$\frac{\sqrt{9+1} - \sqrt{2}}{4-2} = \frac{\overset{1.748}{\sqrt{10}-\sqrt{2}}}{2} = 0.87$$

$$= \frac{1}{1.144}$$

However, if $X = \frac{h}{6}$ while $b = \frac{h}{4}$ use $h = 12$, $b = 3$, $x = 2$

get $$\frac{\sqrt{(12-2)^2+3^2} - \sqrt{2^2+3^2}}{12-4} = \frac{\sqrt{109} - \sqrt{13}}{8} = \frac{10.44 - 3.61}{8}$$

$$= \frac{6.83}{8} = 0.85_4 = \frac{1}{1.17}$$

84

$$\bar{f}_{x,h/2} = \frac{1}{2\left(\frac{h}{2}-x\right)} \int_{x_1}^{h/2} \left(\frac{z\,dz}{\sqrt{z^2+b^2}} + \frac{(h-z)\,dz}{\sqrt{(h-z)^2+b^2}} \right)$$

$$= \frac{1}{2(h-2x)} \int_{x}^{h-x} \left(\frac{z}{\sqrt{z^2+b^2}} + \frac{(h-z)}{\sqrt{(h-z)^2+b^2}} \right) dz$$

let $y = h - z$

$$= \frac{1}{2(h-2x)} \left[\left| \sqrt{z^2+b^2} \right|_{x}^{h-x} + \int_{h-y}^{y} \frac{y\,(-dy)}{\sqrt{y^2+b^2}} \right]$$

$$= \frac{\cancel{2}}{\cancel{2}(h-2x)} \left(\sqrt{(h-x)^2+b^2} - \sqrt{x^2+b^2} \right)$$

In particular, for $x=0$, get $\bar{f}_{0,h} = \bar{f}_{0,h/2} = \dfrac{\sqrt{h^2+b^2} - \sqrt{b^2}}{h}$

$$= \sqrt{1+(b/h)^2} - b/h$$

Thus, for $b = \frac{h}{4}$, get $\sqrt{1.0625} - 0.25 \simeq 0.78 \approx \frac{1}{1.28}$

* But, in general, for $0 \leq x \leq h/2$, get

← $\bar{f}_{x,h/2} = \dfrac{\sqrt{(h-x)^2+b^2} - \sqrt{x^2+b^2}}{h-2x}$

Now, however, extend to neg. values of x.

3/3/64

seen fraction $= \dfrac{h}{2R}$ where $R = \sqrt{(h+|x|)^2 + b^2}$

strictly $b^2 - x^2$

strictly, allowing for smaller occluding cylinder

get $R = \sqrt{h^2 + 2|x|h + b^2}$

$$f = \frac{h}{2\sqrt{h^2+2|x|h+b^2}}$$ (See next p. 86)

for $x=0$, get $f = \dfrac{h}{2\sqrt{h^2+b^2}}$ in agreement with p. 83

for $|x| = b$, get $f = \dfrac{h}{2\sqrt{h^2+2bh+b^2}} = \dfrac{h}{2(h+b)}$

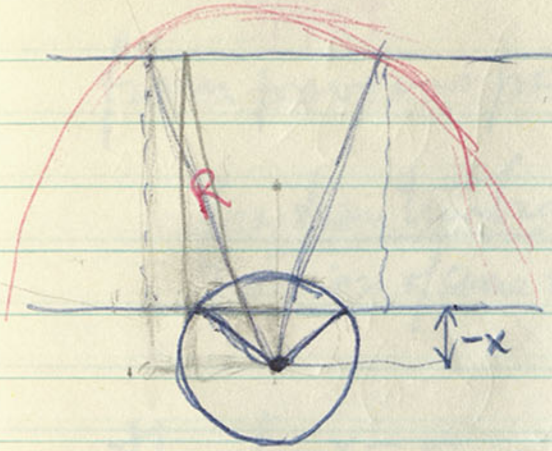
for $h = 4b$, get $\dfrac{4}{2(5)} = 0.4$

for $|x| = b/2$, get $f = \dfrac{h}{2\sqrt{h^2+bh+b^2}}$

here $h=4b$ gives $\dfrac{4}{2\sqrt{16+4+1}} = \dfrac{4}{2(4.583)} = \dfrac{1}{2.29}$

$\underset{21}{}$

$= 0.437$



Consider $-x$
preserve b as uncut value

Then seen fraction $= \dfrac{b-|x|}{2b}$

$= \dfrac{b+x}{2b}$

$\boxed{\text{less } \dfrac{R-h}{2R}}$

But soma profile radius is reduced from b to $\sqrt{b^2-x^2}$
And proportion reduction of soma surface area estimate is by factor $\boxed{\dfrac{b^2-x^2}{b^2}}$.

$$\therefore \frac{\text{fraction ~~dendrs~~ seen}}{\text{fraction of soma surf area}} = \left(\frac{b+x}{2b}\right)\left(\frac{b^2}{b^2-x^2}\right) = \frac{b}{2(b-x)}$$

$$= \frac{b}{2(b+|x|)}$$

Thus, for $|x|=0$, get $\frac{1}{2}$ in disagreement with p. 83

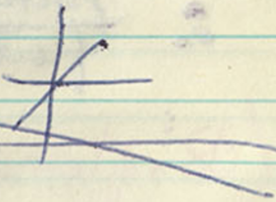
for $|x|=b$, get $\frac{1}{4}$ which is not correct

Integrating from $|x|=0$ to $|x|=b$ gives $\dfrac{b}{2b}\displaystyle\int_0^b \frac{1}{b+y}\,dy$

$$= \frac{1}{2}\Big[\ln(b+y)\Big]_0^b$$

$$\boxed{= \frac{1}{2}\ln 2} = \frac{0.693}{2} = 0.346$$

integrating from 0 to $|x|$ gives $\dfrac{b}{2|x|}\ln\left(\dfrac{b+|x|}{b}\right) = \dfrac{\ln\left(1+\frac{|x|}{b}\right)}{2\frac{|x|}{b}}$



In general, for $0 \le |x| \le b$

have $$\frac{\sqrt{h^2+2h|x|+b^2} - \sqrt{h^2+b^2}}{2|x|}$$

for $h=4b$, get $\sqrt{1+4+16} - \sqrt{1+16}$

$= \sqrt{21} - \sqrt{17}$

$= 4.583 - 4.123$

$= 0.460$

for $|x| = 0$ to b, get $\frac{1}{2}(5 - 4.123) = \frac{0.877}{2} = 0.4385$

3/3/64 p.86

from previous page in red we get

$$\frac{\text{fraction trunks seen}}{\text{fraction of soma surface seen}} = \left(\frac{h}{2\sqrt{h^2+2|x|h+b^2}}\right)\left(\frac{b^2}{b^2-x^2}\right)$$

Then for $X=0$, as before, get $f = \frac{h}{2\sqrt{h^2+b^2}}$

and for $x = b$, get ∞ ∇

but for $|x| = b/2$, get $f = \left(\frac{h}{2\sqrt{h^2+bh+b^2}}\right)\left(\frac{b^2}{b^2-(b/2)^2}\right)$

$$= \left(\frac{2}{3}\right)\frac{h}{\sqrt{h^2+bh+b^2}}$$

But don't really want this

Better integrate $f = \frac{h}{2\sqrt{h^2+2|x|h+b^2}}$

for $0 \leq |x| \leq b/2$

i.e. this mean is $\frac{1}{2\left(\frac{b}{2}\right)}\int_0^{b/2}\frac{2h}{2\sqrt{h^2+2hy+b^2}}\,dy$

$$= \frac{1}{b}\left[\sqrt{h^2+2hy+b^2}\right]_0^{b/2}$$

⟵ $= \frac{1}{b}\left(\sqrt{h^2+hb+b^2} - \sqrt{h^2+b^2}\right)$

$$= \sqrt{1+h/b+(h/b)^2} - \sqrt{1+(h/b)^2}$$

Summary for $h = 4b$

for $x = h/2$	$f = 0.894$	1.12
$x = b$	$\bar{f} = 0.874$	1.144
$x = h/6$	$\bar{f} = 0.854$	1.17
$x = b/2$	$\bar{f} = 0.846$	1.182
$x = 0$	$\bar{f} = 0.78$	1.28
$x = -b/2$	$f = 0.7166$	1.4
$x = -b$	$\bar{f} = 0.667$	1.5

$x = b$	$f = 0.828$	1.208
$x = h/6$	$f = 0.756$	1.323
$x = b/2$	$f = 0.704$	1.42
$x = h/12$	$f = 0.642$	1.56
$x = 0$	$f = 0.485$	2.06
$x = -b/2$	$f = 0.437$	2.29
$x = -b$	$f = 0.40$	2.5

3/3/64

Thus, for overall average from $-x$ to $h+x$, need to combine

$$\frac{\sqrt{h^2+b^2}-\sqrt{b^2}}{h}$$ with weight h from p.84

with $$\frac{\sqrt{h^2+2h|x|+b^2}-\sqrt{h^2+b^2}}{2|x|}$$ with weight $2|x|$ from p.86 bed

$\therefore$ get

$$\bar{f}_{-x\text{ to }h+x} = \frac{\cancel{\sqrt{h^2+b^2}}-\sqrt{b^2}+\sqrt{h^2+2h|x|+b^2}-\cancel{\sqrt{h^2+b^2}}}{h+2|x|}$$

$$\boxed{=\frac{\sqrt{h^2+2h|x|+b^2}-b}{h+2|x|}}$$

for $|x|=b$, get $\dfrac{h+b-b}{h+2b}=\dfrac{h}{h+2b}$; for $h=4b$, get $\frac{4}{6}=0.667$

for $|x|=\frac{b}{2}$, get $\dfrac{\sqrt{h^2+hb+b^2}-b}{h+b}$; for $h=4b$, get $\dfrac{\sqrt{21}-1}{5}$

$$=\frac{3.583}{5}=0.7166=\frac{1}{1.396}$$

$$\approx\frac{1}{1.4}$$

Not quite right because

$$\frac{3}{4}\bar{f}_{h/2,\,h/2} + \frac{1}{4}\bar{f}_{0,\,h/2} \overset{\text{should}}{=} \bar{f}_{0,\,h/2}$$

$$\frac{3}{4}(.846) + \frac{1}{4}(.637) > 0.78$$

$\approx .794$

3/3/64 88

One more case

If we know it is cut, how about taking x from $-b/2$ to $+b/2$

$-b/2$ to zero we already have

0 to $+b/2$ on p. 84 use these limits

~~$\frac{1}{(h-b)}\left(\sqrt{(h-b/2)^2+b^2} - \sqrt{(b/2)^2+b^2}\right)$~~

~~get $\frac{?}{b}\left[\sqrt{z^2+b^2}\right]_0^{b/2} = \frac{\sqrt{(b/2)^2+b^2}-b}{b/2} = \frac{\sqrt{1.25}-1}{0.5}$~~

~~if $h=4b$, get $\frac{\sqrt{1.25}-1}{0.5} = \frac{0.118}{0.5} = 0.$~~

$$\bar{f}_{0,b/2} = \frac{1}{2(b/2)}\int_0^{b/2}\left(\frac{z\,dz}{\sqrt{z^2+b^2}} + \frac{(h-z)\,dz}{\sqrt{(h-z)^2+b^2}}\right)$$

$$= \frac{1}{b}\left\{\left[\sqrt{z^2+b^2}\right]_0^{b/2} - \left[\sqrt{y^2-b^2}\right]_h^{h-b/2}\right.$$

$$= \frac{1}{b}\left\{\sqrt{1.25b^2} - b + \sqrt{h^2-b^2} - \sqrt{(h-b/2)^2-b^2}\right\}$$

$$= \sqrt{1.25} - 1 + \sqrt{(h/b)^2-1} - \sqrt{(h/b-1/2)^2-1}$$

for h=4b

$$= 1.118 - 1 + \sqrt{15} - \sqrt{49/4-1}$$ $\sqrt{11.25}$

$$= 0.118 + \underset{3.873}{\cancel{1.732}} - 3.354$$ $\boxed{1.88}$

Table $= 0.637$ average with 0.437 & get .532

Also people to see or write. Kathryn Thomas (Minnesota)
Tom Smith
Fitzhugh
Aitken
Braitenberg
Dun Fu Tang

3/4/64 89

Stocktaking of Papers to be Completed in Coming Year

for Eccles Commemorative Volume — 6 pages
Dendritic Synaptic Patterns: Experiments with a Mathematical Model

Paper on Branching Extrapolation for Dendritic Radial Symmetry
" " Dendritic Surface Area Estimates from Aitken's Data
" " Dendritic Input Conductance - — — — .
" " Analysis of Sholl's Data

Theoretical Dists of Ve & Vi for spherical soma

Theoret. Dist of Ve for asymmetric dendritic Ezra & Jeanne neurons

Theoret ~~Dist~~ transients of Ve for radially symmetric case (Stockholm

Theory for Ve with synchronous activity in cortical layers.

Comparison of Theory & Exp. for Ve antidromic action potentials in Olfactory Bulb.

Math. Model for Computation of Action Potential Propagation into Regions of Changing Geometry & Safety Factor.

Calculation of miniature epsp's generated at different distances, for comparison with Katz.
Also of location degeneracies & effect of β value.
Hypothesis relating Synaptic Clefts to Giant Extracellular Action Potentials and to Synaptic Mechanism.

Diagrammatic comparison of single cell, pops of cells, layers.

Effect probably cannot be attributed to a net increase in ionic conc., but rather, to an isotropic effect. This may require careful analysis.

3/10/64

Talked ~~today~~ - at Mones' introduction, with Stan Appel
He has worked under Gordon Tomkins on bacterial genetics and is very much concerned with neurology, learning & its molecular biological substrate.

He says that grey matter has great excess of RNA & was concerned with link from synaptic region to hillock trigger region. I commented that increased core conductance was important & while I had originally thought of increased cross section, increased ionic core conductance could also do it.

~~This led me to suggest that if neurofibrils~~

He thought of neurofibrils & I pointed out if RNA collects in dendritic core, its fixed charge would hold cloud of ions which could conduct. He says fixed charge is neg. & so cloud is cations. If RNA is in chain arrangement (neurofibrils), this could conduct ions almost as a copper wire conducts electrons.

Question, how to selectively favor one dendritic tree & draw RNA into dendrite. Answer, if the acute conditioning process also has a longer lasting low level depol. in dendritic periphery assoc. with it, the core current, from periphery to soma, will set up a pot. gradient that will attract the ⊖ charged RNA up into the core & even tend somewhat to draw out of neighboring dendrites. Net result is to increase weighting to that dendritic tree. Two effects (1) activity of cell produces RNA at soma (2) depol of particular tree favors diffusion of RNA into that tree (3) Result is to increase weight of that tree in integrative activity.

Remember that $\mathcal{E}$ does not corresp exactly to Na
$\mathcal{J}$ " " " " K

because G_K contains a little also, but not much.

$$\tau\dot{V} = -\underline{(1+\mathcal{E}+g)}V + \overbrace{g_D(V_+ + V_- - 2V)}^{\text{not when isolated}} + \mathcal{E} - \beta\mathcal{J} + \Psi$$

for voltage clamping, calc $-\Psi$ for $\dot{V}=0$, $V=$ const

Dirk says this has same Topological properties as H&H

anticipates two questions ① How would it respond to voltage clamp?
② How does impedance change.

3/10/64

Talked this afternoon to Dick Fitzhugh

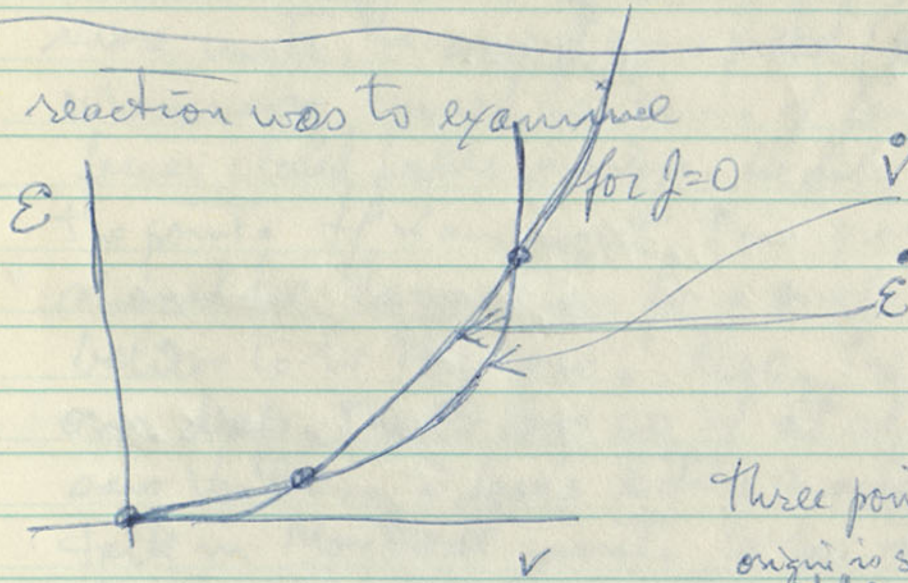
presented the equations of my Ojai paper

Then added the axonal equations (non-linearity in this form)

$$\dot{\mathcal{E}} \propto k_1 (V)^3 - (k_2 + k_3 j)\mathcal{E}$$

$$\dot{j} \propto (k_2 + k_3 j)\mathcal{E} - k_4 j$$

His reaction was to examine



$\dot{V}=0$ isocline $V = \frac{\mathcal{E}}{1+\mathcal{E}}$

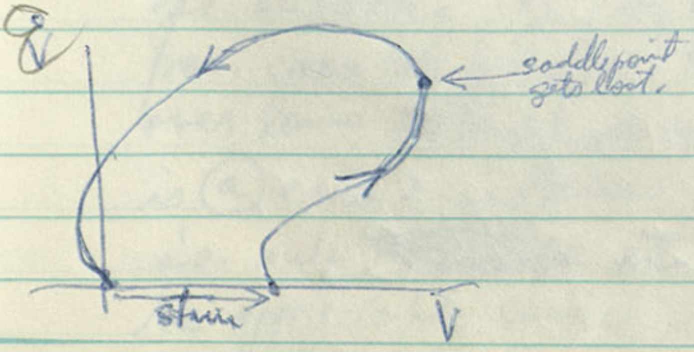
$\dot{\mathcal{E}}=0$ $\mathcal{E} = \frac{k_1}{k_2} V^3$

Three points of intersection
origin is stable
middle one is saddle point.

as j begins to increase

$\dot{V}=0$ corresp to $V = \frac{\mathcal{E} - 0.1 j}{1+\mathcal{E}+j}$

Curve moves up



$\dot{\mathcal{E}}=0$ corresp to $\mathcal{E} = \frac{k_1 V^3}{k_2 + k_3 j}$

Curve moves down

Saddle point shifts to the right.
& gets lost!

3/11/64

Talked to Van Buren a couple of weeks ago. He was recording group antidromic responses in ventral horn with steel needle for stim of muscle nerve (gastroc) & was plotting amplitudes of ⊕ & ⊖ vs. position in V.R. Got rather sharp spatial decrement. Considerable resemblance to records I did with Eccles in 1949. Van Buren noticed that negativity tend to fractionate into 4 or 5 steps, with graded stim strength. I commented that this fits idea of limited closed field for the negativity. My thought was that the positivity would be the sum of many more units, because of open field (for impulse on axon). whereas neg. would be sum of fewer, because fewer closed fields overlap. He didn't quite seem to get the point. If I am right, this group ⊕/⊖ ratio should be larger than for a single cell. This, I believe to be the case. Also, the ⊕ should turn over deep, the ⊖ less so if at all. Yesterday, I saw Van Buren at Jose's lecture & asked him how his talk in Montreal went. So-So. ~~He said he tried~~ ~~the~~ He was asked two questions that he mentioned to me (1) explain the neg. — he tried to explain by means of my superposition argument where neg. swamps pos. — apparently this is hard to get across. (2) They wanted to know why the pos. was so brief — since impulse approaches over long distance. He could not answer. My answer is ⓐ core resistance, ⓑ nodes have small area. i.e. only ~~the test po~~ at near approach would there be appreciable source current flowing from soma & dendrites. Maybe this should be written up sometime.

Consider dimensions

For hot kinetics of 64791.0666

$k_1 = RACT*RINB = 600*50 = 3\times10^4$

$k_2 = ROUTB = 20$

$\varepsilon = 600*B$

$k_3 = QENCHB/QENCHA = 60/20 = 3$

$j = 20*C$

$k_4 = ROUTC = 3$

in 64791.0647 same hot kinetics also $\frac{QENCHA}{RACT} = \frac{20}{600} = 1/30 = .0333$

peak B $\simeq .76 \rightarrow \varepsilon \simeq 450$ with C $\simeq .49 \rightarrow j \simeq 10$

later peak C $\simeq 2.6$ $j \simeq 50$ with B $\simeq .026 \rightarrow \varepsilon \simeq 12$

see p. 26, for V^2, RACT=600, RINB=2.

For cool kinetics of 64791.0669

$k_1 = 500*30 = 1.5\times10^4$

$\varepsilon = 500*B$

$k_2 = 20$

$j = 15*C$

$k_3 = 40/15 = 2.667$

$k_4 = 3$

in 64791.0646 same cool kinetics

peak B $\approx .58 \rightarrow \varepsilon \approx 300$ also $\frac{QENCHA}{RACT} = \frac{15}{500} = .03$

later peak C $\approx 2.2 \rightarrow j \approx 33$

with C $\simeq .51 \rightarrow j \approx 7.5$

These two sets of kinetic consts have much in common

$k_3 \simeq k_4 \simeq \frac{3}{20} k_2$ and $QENCHA/RACT \simeq 1/30$

Also peak j is approx 0.11 of peak ε

Most important difference is factor of 2 in k_1 which yields factor of 1.5 in peak ε.

3/11/64 $\tau\dot{V} = -(1+\mathcal{E}+\mathcal{J})V + \mathcal{E} + \beta\mathcal{J} + \psi + \tau u_{ij}\sum(V_j - V_i)$

Should consider investigating impedance & clamp response of my impulse model. Ought to consider how much programming might be needed. Can do this for a single path, or a few patches. But need to consider relation between equations in $\mathcal{E}$ & $\mathcal{J}$ as given Fitzhugh and equations in RACT etc. pp 50, 61

$\mathcal{E}$ corresp to B*RACT

$\mathcal{J}$ corresp to C*QENCHA

p.50 $\therefore \tau\dot{B} = RINB * V^3 - B*(C*QENCHB + ROUTB)$ for $V \geq 0$

not for $V < 0$

means $\tau\dot{\mathcal{E}} =$ [illegible] $RACT * \dot{B}$

$= (RACT * RINB)*V^3 - \mathcal{E}*\left(\mathcal{J}*\frac{QENCHB}{QENCHA} + ROUTB\right)$

$\therefore$ for $\boxed{\tau\dot{\mathcal{E}} = k_1 V^3 - (k_2 + k_3\mathcal{J})\mathcal{E}}$

$k_1 = RACT * RINB$

$k_2 = ROUTB$

$k_3 = QENCHB/QENCHA$

$\tau\dot{C} = BTOC - ROUTC * C$

$\tau\dot{\mathcal{J}} = QENCHA * \dot{C}$

$= \cancel{QENCHA} * \left(\frac{\mathcal{E}}{RACT}\right) * \left(\frac{\mathcal{J}}{\cancel{QENCHA}} * QENCHB + ROUTB\right) - ROUTC * \mathcal{J}$

$= \left(\frac{QENCHA * ROUTB + QENCHB * \mathcal{J}}{RACT}\right)\mathcal{E} - ROUTC * \mathcal{J}$

$\therefore$ for $\boxed{\tau\dot{\mathcal{J}} = \left(\frac{QENCHA}{RACT}\right)(k_2 + k_3\mathcal{J})\mathcal{E} - k_4\mathcal{J}}$

$k_4 = ROUTC$

k_2 & k_3 are above

factor QENCHA/RACT

WXR91C & WXR92C do not permit neg V in expression for $\dot{B}$, this prevents neg B and this, in turn, prevents neg C. With V^2, might not need this.

(Mrs. Kennedy 64648)

Time charged to 40029 in 1963-4 fiscal year

			Programming
July			
Aug			
Sept	0.8 hour	$143.50	
Oct.	3.6	623.	
Nov.	0.7	119.	
Dec.		638.75	
Jan.		829.50	
Feb.		346.50	365
Mar.		337.75	230
April		743.75	325
May		607.25	485
June			
Est for year		5166	2000

Keypunch Mrs. Ricketts, Mrs. Nier

Bldg 2 - Dr. Coulter Ext. 64295 has keypunch

Messenger service - phone Mrs. Costello 63058
or Mr. Quave 64648

Debugging	① Noonan Thompson	65181
	② Moura Hammond	65181
G-1-3B	③ Vernon Zander	66037
	④ Bob Brunelle	65181

Prideaux / 66021 4th floor B wing, Bldg 31

Computation People

Bob Fillard
Mrs. Culpepper
Dolores Forcier } 66184

Jerry Farlow 66037
Betty Garber) pp. 65–66
pp 75–76

Paper of Spherical Neuron Membrane

~~I wish to begin by emphasizing~~
~~And I do not assume~~

Although ~~T~~here are neurons with almost spherical somas, I wish to emphasize that this paper is.

BVP

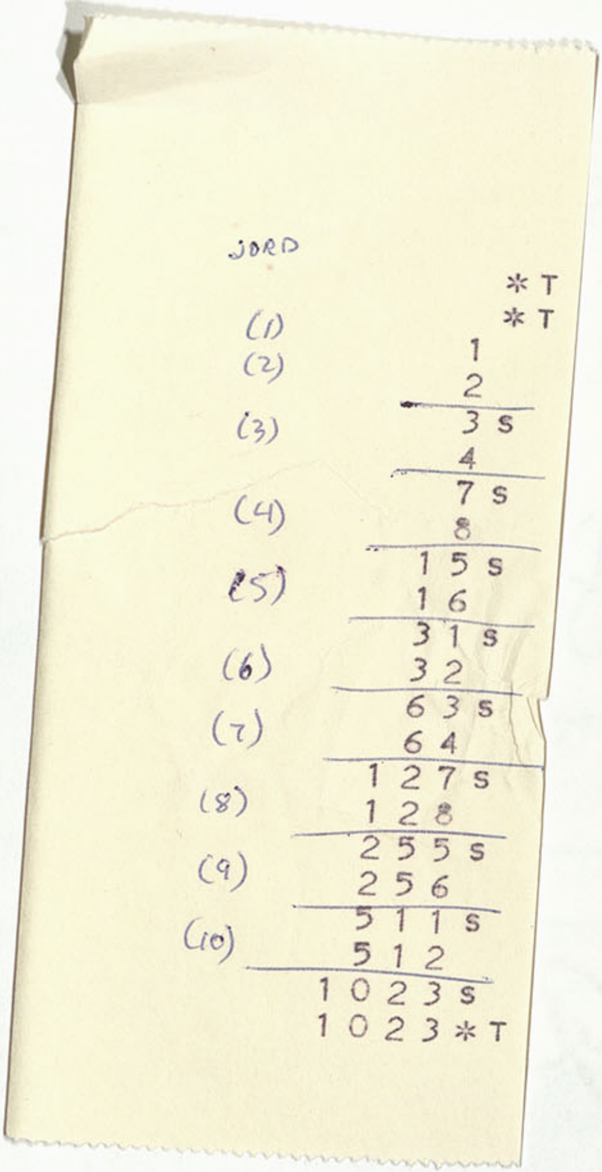
$$J = \frac{1}{c}\frac{du}{dt} - w - \left(u - \frac{u^3}{3}\right)$$

$$c\frac{dw}{dt} + bw = a - u$$

variables u, w & J of BVP correspond
to (V,m) (h,n) I

Farlow

44-66037



```
JORD
                  * T
(1)               * T
(2)             1
                2
              -----
(3)             3 s
                4
              -----
                7 s
(4)             8
              -----
               15 s
(5)            16
              -----
               31 s
(6)            32
              -----
               63 s
(7)            64
              -----
              127 s
(8)           128
              -----
              255 s
(9)           256
              -----
              511 s
(10)          512
              -----
             1023 s
             1023 * T
```

p. 92

note re Van Buren

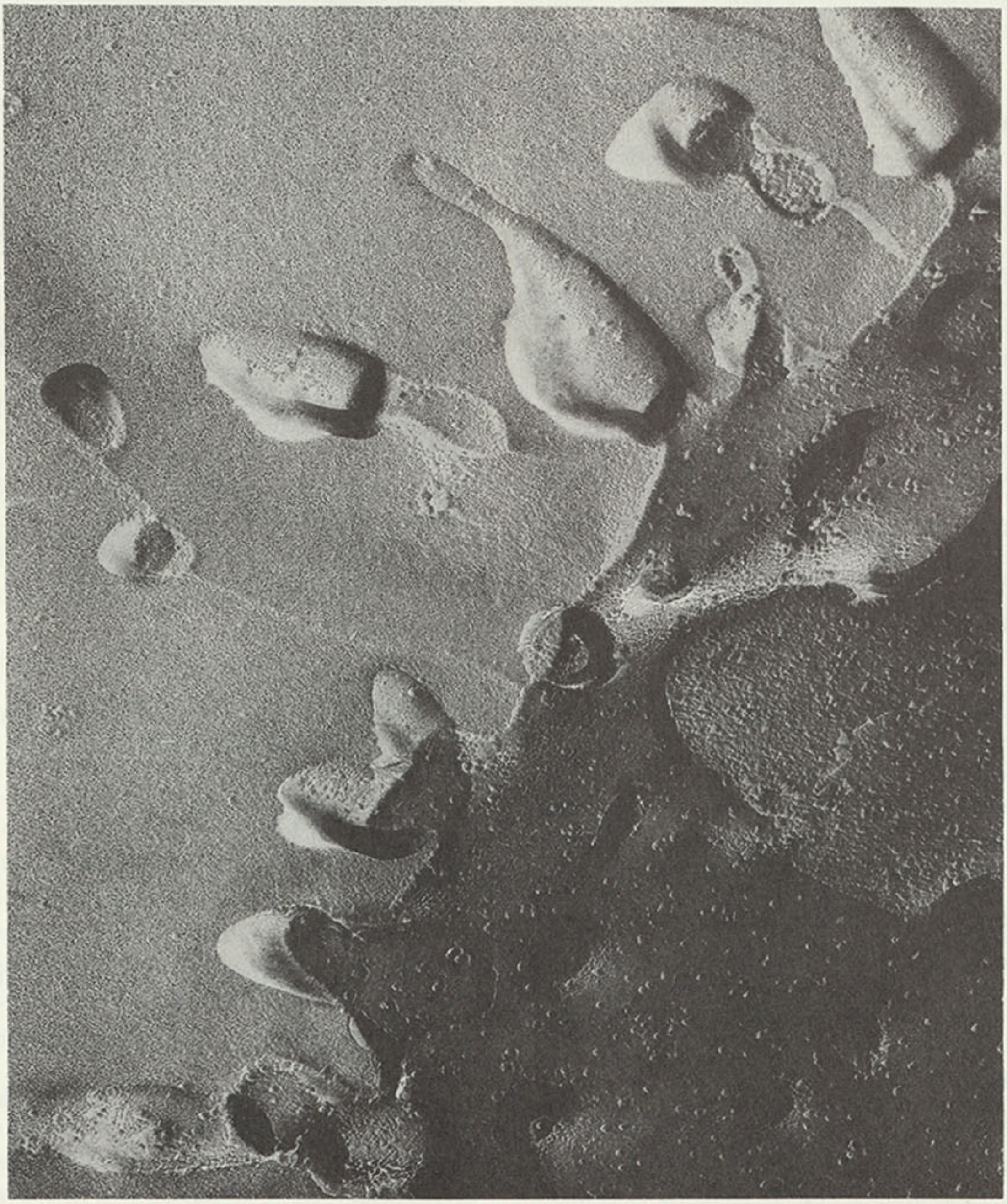
UNIVERSITY OF CALIFORNIA EXTENSION, BERKELEY

Biological Electron Microscopy

JUNE 19-30, 1967

Botanical Histochemistry

JULY 10-28, 1967



Letters and Science Extension in cooperation with
The Electron Microscope Laboratory / University of California, Berkeley

BIOLOGICAL ELECTRON MICROSCOPY X 403.

JUNE 19-30, 1967

Rapid advances in electron microscopic applications to biological materials and the development of new electron microscopic techniques make electron microscopy an increasingly important field of modern science. This course, conducted on the postgraduate level, is intended as a systematic introduction to the theory and application of electron microscopy of biological materials. It will utilize a broad spectrum of speakers and new laboratory equipment to provide a basic understanding of modern techniques for electron microscopy and to review recent advances which electron microscopy has produced in the biological sciences.

Objectives

To provide instruction and experience in basic techniques in electron microscopy of biological materials; to develop the participants' ability to evaluate the suitability of problems for electron microscopic investigation; to provide a basic knowledge of the application of electron microscopic methods to specific research areas in biology and medicine; to demonstrate advanced techniques of specimen preparation and electron microscopy; and to advise on the planning, establishment, and organization of electron microscope laboratories.

Content

The course will include a comprehensive series of lectures and demonstrations surveying electron optics and electron microscopy theory. The demonstrations will cover techniques and applications of biological electron microscopy, with the aim of helping participants learn about the types of laboratory equipment, preparation of specimens, operation of the electron microscope, and specific modern electron microscopy techniques. Approximately half of the lectures will feature application to specific biological or medical areas.

Each participant will be individually scheduled for lectures and the several concurrent laboratory and demonstration sections; in this way it is possible to accommodate different levels of experience and individual interests while keeping group sizes small, assuring participants ample opportunity for guidance and discussion. Research material appropriate to each participant's field of interest will be provided. Participants may elect to bring suitable specimens to the course and to prepare and examine them as part of the laboratory exercises. Those who do so must submit a research plan with their application.

An exclusive course manual will be provided, and a library and reading room will be available for study. The laboratory will also be open in the evenings and on the weekend. A social program is included to provide informal opportunities to exchange views and extend academic associations.

For Whom Intended

The course is intended for scientists in colleges, universities, and industry who need to be familiar with electron microscopy, and for electron microscopists seeking a refresher course that includes the latest techniques. The course should be of interest to senior investigators, postdoctoral fellows, advanced graduate students, and professional technicians.

Daily Schedule

Morning and Afternoon	Concurrent Lectures and Laboratories (two laboratories each morning and afternoon)
Evening	Demonstrations and Laboratories
Weekend (June 24–25)	Laboratory open during the day

Lecture Schedule

June 19

Morning	Registration and Orientation
Afternoon	Specimen Preparation. Discussion
Evening	T.V. Tapes: Specimen Preparation

June 20

Morning	Electron Optics
Afternoon	Electron Optics
Evening	Reception

June 21

Morning	Ultracytochemistry
Afternoon	Ultracytochemistry
Evening	T.V. Tapes: Microtomy

June 22

Morning	Film Making and Knife Breaking
Afternoon	Light and Electron Microscopy Methods
Evening	T.V. Tapes: Shadowing and Negative Staining

June 23

Morning	Scanning Microscope Autoradiography
Afternoon	Excursion

June 26

Morning	Molecular Biology and Virology
Afternoon	Molecular Biology
Evening	Autoradiography

June 27

Morning	Freeze Etching / Membranes
Afternoon	Botanical Applications
Evening	Freeze Etching

June 28

Morning	Zoological Applications
Afternoon	Filamentous Organelles
Evening	Light and Electron Microscope Applications

June 29

Morning	Protozoa and Spermiogenesis
Afternoon	Chromosomes
Evening	Special Demonstration

June 30

Morning	Biochemical Cytology
Afternoon	To be announced
Evening	Banquet

Demonstrations

Operation of Electron Microscopes

Sectioning

Knife Breaking and Film Making

Photography

Fixing and Embedding

Freeze Etching

DNA Spreading

Magnification Calibration

Resolution Determination

Microscope Alignment

Microscope Maintenance

Autoradiography

Light Microscopic Techniques

Stereo Electron Microscopy

Scanning Microanalysis

Negative Staining

Heavy Metal Shadowing Technique

Equipment Evaluation and Analysis

Labeled Antibodies

Special Discussions

Organization and Planning of Laboratories

Financing and Administration of Laboratories

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BLDG. 31, ROOM 9-A-17
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Cover Photograph
Freeze fracture replica of the surface of a pig kidney tissue culture cell showing inner and outer membrane aspects and micro-villi. 100,000 X. By Melvin Weinstock, Department of Zoology, University of California, Berkeley.

Inside Photograph
Root cap of onion root tip (Allium cepa var. white globe). Periodic acid-Shiff reagent (PAS) used to localize insoluble carbohydrates. By William A. Jensen, Department of Botany, University of California, Berkeley.

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 TITLEWXR791C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C   2.4.64  ADDED TEST AT 460.
C     1.21.64  MOD OF WXR786C.
C   1.10.64  TO GO WITH WXR82C        1.16.64       1.17.64
C   1.8.64  QENCHA IN CALL ARGUMENT
C   12.31.63  ADD AFPOS,  VMIN = -.1
C   12.27.63  MOD OF WXR786C TO USE WXR80C FOR PLOT INSTEAD OF WXR81C.
C   12.26.63  MOD OF WXR785C.    ADDED CLOCK.
C   12.18.63  MOD OF WXR783C.    THIS IS CUBED VERSION.
C   12.14.63  MOD OF WXR781C       12.17.63
C   12.9.63   MOD WITH CHANGED DIMENSIONS.  NC.  AX-S-D ORDER.
C   12.5.63  MOD OF 707 AND 709C.
  902 FORMAT (18HOUTPUT OF WXR791C. /
     X 24HDR. W. RALL, EXT. 64325. / 15HBLDG. 31, 9A23.   // )
C
      DIMENSION VAZ(14),VBZ(14),         AB(14),AC(14),BB(14),BC(14),
     1 VAP(251),VBP(251),TK(251),ZJ(251),VATZ(251,14),VBTZ(251,14),
     2 KTA(10),KTB(10),BEB(10,10),BJC(10,10),KTSP(10),VSP(10)
  900 FORMAT (1H0)                                                      WXR701C
  901 FORMAT (1H1)                                                      WXR701C
  903 FORMAT (22HEND OF WXR791C OUTPUT.)
  904 FORMAT (////)                                                     WXR701C
  120 WRITE OUTPUT TAPE 15, 902                                         WXR701C
  140 READ INPUT TAPE 1,  951, NC,
     X PROBNO,NT,NSTEP,DT,DZ,NEJ,NSP,IFTEST
  951 FORMAT (I1,9X,F10.4,2(5X,I5),2F10.4,2(3X,I2),I10)
  921 FORMAT(2HNC, 12X,6HPROBNO,8X,2HNT,5X,5HNSTEP,8X,2HDT,8X,2HDZ,2X,
     X 3HNEJ,2X,3HNSP,4X,6HIFTEST /)
  141 IF END OF FILE 142,150                                            WXR701C
  142 WRITE OUTPUT TAPE 15, 903                                         WXR701C
  144 STOP                                                              WXR701C
  150 WRITE OUTPUT TAPE 15,  920
  920 FORMAT( 28HRECAP OF INPUT INFORMATION.  ////)
  151 WRITE OUTPUT TAPE 15,  921
  160 WRITE OUTPUT TAPE 15, 951, NC,
     X PROBNO,NT,NSTEP,DT,DZ,NEJ,NSP,IFTEST
  161 WRITE OUTPUT TAPE 15,  904
 1611 IFSPOT = IFTEST - 100
C1611  SEE 481.  E.G. IFTEST= 6112185 MEANS THAT FROM KT=61 TO KT=121 GIVE TEST
C    PRINT IN RUNGE KUTTA FOR EVERY FIFTH  KT.    6112115 GIVES NABC TEST.
 1612 IF(IFSPOT) 162,162,1613
 1613 KMSPOT = IFTEST/100
 1614 KSPOT = KMSPOT/1000
      KK = 1000*KSPOT
 1615 MSPOT = KMSPOT - KK
      KMCENT = 100*KMSPOT
 1616 IFTEST = IFTEST - KMCENT
 1617 KNRK = KSPOT
 1618 KRTEST = 0
 1619 NRKABC = IFTEST - 80
 1620 IF(NRKABC) 1621,1621,173
```

```
 1621 NABC = IFTEST - 10
 1622 KNABC = KSPOT
 1623 GO TO 180
  162 NRKABC = IFTEST - 80
  163 IF(NRKABC) 168,168,164
  164 KRTEST = 0
  165 KNRK = 1
  166 GO TO 173
C 166 KRTEST=1 CAUSES TEST PRINT WITHIN KUTTA-RUNGE SUBROUTINES. SEE 482-3
  168 KRTEST = 0
  169 IF(IFTEST-10) 173,173,170
  170 NABC = IFTEST - 10
C 170 THIS IS USED AT 410 FOR SELECTED PRINT.
  171 KNABC = 1
  172 GO TO 180
  173 NABC = 0
  180 READ INPUT TAPE 1,  952, NC,
     X NPLT,LJZPLT,NSPPLT,NSKIPT,IFHL,NPLZ,LKTPLZ,NSPPLZ,NSKIPZ
  922 FORMAT(6X, 4HNPLT, 4X, 6HLJZPLT, 4X, 6HNSPPLT, 4X, 6HNSKIPT,
     X10H IFHL NPLZ,4X,6HLKTPLZ, 4X, 6HNSPPLZ, 4X, 6HNSKIPZ /)
  952 FORMAT (I1, I9, 3I10, 2I5, 3I10)
  190 WRITE OUTPUT TAPE 15, 922                                         WXR701C
  200 WRITE OUTPUT TAPE 15, 952, NC,                                    WXR701C
     X NPLT,LJZPLT,NSPPLT,NSKIPT,IFHL,NPLZ,LKTPLZ,NSPPLZ,NSKIPZ
  210 WRITE OUTPUT TAPE 15, 904                                         WXR701C
  220 READ INPUT TAPE 1,                                                WXR701C
     X 953, NC,UA,UD,USA,USD,CORE,NJA,NJD,IFVE,IFAB
  953 FORMAT(I1, 4X, 5F10.5, 3I5, I10)
  923 FORMAT (8X,2HUA,8X,2HUD,8X,3HUSA,7X,3HUSD,9X,4HCORE,3X,3HNJA,2X,
     X 3HNJD, 5H IFVE, 6X, 4HIFAB /)
  221 WRITE OUTPUT TAPE 15, 923
  222 WRITE OUTPUT TAPE 15,
     X 953, NC,UA,UD,USA,USD,CORE,NJA,NJD,IFVE,IFAB
  223 WRITE OUTPUT TAPE 15, 904
C      JH=INDEX OF HILLOC.  JS=INDEX OF SOMA.  JT=INDEX OF TRUNKS.
  250 JH = NJA
  251 JS = JH + 1
  252 JT = JS + 1
  253 NZ = JS + NJD
  254 NLZ = NZ - 1
  230 READ INPUT TAPE 1,
     X 954, NC, (VAZ(JZ), JZ=1, 14)
  954 FORMAT(I1, 6X, 14F5.2)
  924 FORMAT(35HSPECIFICATION OF INITIAL VAZ=VBZ.   /)
  231 WRITE OUTPUT TAPE 15, 924
  232 WRITE OUTPUT TAPE 15,
     X 954, NC, (VAZ(JZ), JZ=1, 14)
  233 WRITE OUTPUT TAPE 15, 904
  240 READ INPUT TAPE 1,
     X 955, NC,     RACT,RINB,RINC,QENCHA,ROUTB,ROUTC,QENCHB,AFPOS
  955 FORMAT (I1, 4X, 7F10.5, F5.2 )
  925 FORMAT (9X,  4HRACT, 6X, 4HRINB, 6X, 4HRINC, 4X, 6HQENCHA, 5X,
     X 5HROUTB, 5X, 5HROUTC, 4X, 6HQENCHB  2X, 5HAFPOS  /)
```

```
  243 WRITE OUTPUT TAPE 15, 925
  244 WRITE OUTPUT TAPE 15,
     X 955, NC,      RACT,RINB,RINC,QENCHA,ROUTB,ROUTC,QENCHB,AFPOS
  245 WRITE OUTPUT TAPE 15,  904
 2451 IF(NEJ)2461,2461,2452
 2452 WRITE OUTPUT TAPE 15, 936
 2453 READ INPUT TAPE 1,
     X 966,NC,KEJ,KTA(KEJ),KTB(KEJ),(BEB(JZ,KEJ),JZ=JT,NZ),
     X (BJC(JZ,KEJ),JZ=JT,NZ)
  966 FORMAT(I2,I3,2I5,2X,20F5.2)
  936 FORMAT(15H  KEJ  KTA  KTB,4X,12HBEB(JZ,KEJ). 38X,12HBJC(JZ,KEJ)./)
 2454 WRITE OUTPUT TAPE 15,
     X 966,NC,KEJ,KTA(KEJ),KTB(KEJ),(BEB(JZ,KEJ),JZ=JT,NZ),
     X (BJC(JZ,KEJ),JZ=JT,NZ)
 2455 IF(KEJ-NEJ) 2456,2460,2460
 2456 WRITE OUTPUT TAPE 15, 900
 2457 GO TO  2453
 2460 WRITE OUTPUT TAPE 15, 904
 2461  IF(NSP)248,248,2462
 2462 WRITE OUTPUT TAPE 15, 937
 2463 READ INPUT TAPE 1,
     X 967,NC,KSP,KTSP(KSP),VSP(KSP)
  967 FORMAT(I2,I9,I10,5X,F10.5)
  937 FORMAT(7X,3HKSP,6X,4HKTSP,9X,3HVSP /)
 2464 WRITE OUTPUT TAPE 15,
     X 967,NC,KSP,KTSP(KSP),VSP(KSP)
 2465 IF(KSP-NSP) 2466,2470,2470
 2466 WRITE OUTPUT TAPE 15, 900
 2467 GO TO 2463
 2470 WRITE OUTPUT TAPE 15, 904
  248 VMAX = 1.
  249 VMIN = -.1
  201 MKTPLZ = 1 + NPLZ*LKTPLZ
  202 IF(MKTPLZ - NT) 205,205,203
  203 MKTPLZ = NT
  205 MJZPLT = NPLT*LJZPLT
  206 IF(MJZPLT - NZ) 255,255,207
  207 MJZPLT = NZ
  255 IF(NZ-14) 260,260,256
  256 WRITE OUTPUT TAPE 15, 257
  257 FORMAT(36HSTOP BECAUSE NZ IS GREATER THAN 14.  /)
  258 GO TO  140
C 260 HERE GENERATE T VALUES, BEGINNING WITH ZERO.
  260 TK(1) = 0.
  261 DO 270 KT=2,NT
  270 TK(KT) = TK(KT-1) + DT
  280 ZJ(1) = 0.5*DZ
  281 DO 282 JZ=2, NZ
  282 ZJ(JZ) = ZJ(JZ-1) + DZ
  311 IF(NSTEP) 312,312,320
  312 NSTEP = 1
  320 XND = NSTEP                                                   WXR701C
  330 DELT = DT/XND                                                 WXR701C
```

```
  331 HAFDEL = .5*DELT
  332 DELSIX = DELT/6.
  999 FORMAT (/ 15HELAPSED TIME IS  I6,  10H  SECONDS. /)
  366 ICLOCK = 1
      CALL NIH104 (ICLOCK,JCLOCK)
      WRITE OUTPUT TAPE 15,999, JCLOCK
  346 WRITE OUTPUT TAPE 15, 901
  350 KT = 1                                                          WXR701C
  351 KEJ = 1
  352 KSP = 1
C 360 HERE TO 390 TAKE CARE OF ZERO AND NONZERO INITITIAL CONDITIONS.
  360 DO 365 JZ=1, NZ
  361 AB(JZ) = 0.
  362 AC(JZ) = 0.
  363 BB(JZ) = 0.
  364 BC(JZ) = 0.
  365 VBZ(JZ) = VAZ(JZ)
C 370 THIS PROVIDES FOR SYNAPTIC E AND J.
  370 IF(NEJ) 390,390,3701
 3701 IF(KEJ-NEJ) 371,371,390
  371 IF(KT-KTA(KEJ)) 390,380,372
  372 IF(KT-KTB(KEJ)) 390,390,373
  373 DO 375 JZ=JT,NZ
  374 BB(JZ) = 0.
  375 BC(JZ) = 0.
  376 KEJ = KEJ + 1
  377 GO TO 3701
  380 DO 382 JZ=JT,NZ
  381 BB(JZ) = BEB(JZ,KEJ)
  382 BC(JZ) = BJC(JZ,KEJ)
  390 IF(NSP) 410,410,3901
 3901 IF(KSP - NSP) 391,391,410
  391 IF(KT-KTSP(KSP)) 410,392,395
  392 VAZ(1) = VSP(KSP)
  393 GO TO 410
  395 KSP = KSP + 1
  396 GO TO 3901
C 410 SEE 169-171.  PRINT ONLY WHEN KT IS A MULTIPLE OF  NABC = IFTEST-10.
  410 IF(NABC)  430,430,4101
 4101 IF(IFSPOT) 411,411,4102
 4102 IF(KT-KSPOT) 430,420,4103
 4103 IF(KT-MSPOT) 411,420,430
  411 IF(KT-KNABC)  430,420,412
  412 KNABC = KNABC + NABC
  413 GO TO 411
  420 WRITE OUTPUT TAPE 15, 931, KT, TK(KT), IFAB, PROBNO
  931 FORMAT ( /3HKT=, I3, 3X, 3HTK=, F7.3, 5X,22HTEST PRINT IN WXR791C.
     X 10X, 5HIFAB=, I3, 35X, 8HPROBNO., F10.4 /)
  421 IF(IFAB) 422,422,423
  422 WRITE OUTPUT TAPE 15, 942, (VAZ(JZ), JZ=1, NZ)
 4221 WRITE OUTPUT TAPE 15, 942, (AB(JZ), JZ=1,NZ)
 4222 WRITE OUTPUT TAPE 15, 943, (AC(JZ), JZ=1,NZ)
  423 IF(IFAB) 430,424,424
```

```
  424 WRITE OUTPUT TAPE 15, 942, (VBZ(JZ), JZ=1, NZ)
 4241 WRITE OUTPUT TAPE 15, 942, (BB(JZ), JZ=1,NZ)
 4242 WRITE OUTPUT TAPE 15, 943, (BC(JZ), JZ=1,NZ)
  942 FORMAT (2X, 14(1X, F7.4))
  943 FORMAT (2X, 14(1X, F7.4)/)
  430 DO 450 JZ=1, NZ
  440 VATZ(KT,JZ) = VAZ(JZ)
  450 VBTZ(KT,JZ) = VBZ(JZ)
  460 TESTV = VAZ(JS) - 5.
  461 IF(TESTV) 480,480,462
  462 IFVE = 0
  463 NPLZ = 0
  464 NT = KT
  465 WRITE OUTPUT TAPE 15, 466, KT
  466 FORMAT (//30HDISCONTINUE COMPUTATION AT KT=   I3,
     X56H,  BECAUSE VAZ(JS) EXCEEDS 5.  NOW GO TO 520 WITH NT=KT.  //)
  467 GO TO 520
  480 IF(KT-NT) 481,520,520
  481 IF(NRKABC) 491,491,4810
 4810 IF(IFSPOT) 482,482,4811
 4811 IF(KT-KSPOT) 490,483,4812
 4812 IF(KT-MSPOT) 482,483,490
  482 IF(KT-KNRK) 490,483,485
  483 KRTEST = 1
  484 GO TO 491
  485 KNRK = KNRK + NRKABC
  486 GO TO 482
  490 KRTEST = 0
  491 IF(IFAB)  492,492,494
C 491 -1=ACTIVE ONLY.  0=ACTIVE AND PASSIVE.  +1=PASSIVE ONLY.
C 492 THIS SUBROUTINE PERFORMS RUNGE KUTTA FOR ACTIVE DENDRITIC MEMBRANE.
  492 CALL WXR91C (VAZ,AB,AC,
     1  KT,  DELT,NSTEP,HAFDEL,DELSIX,KRTEST,
     2 NZ,NLZ,JS,JH,JT,UA,UD,USA,USD,
     3 RACT,RINB,RINC,QENCHA,ROUTB,ROUTC,QENCHB,AFPOS)                MAINPRO
  494 IF(IFAB)  500,495,495
C 495 THIS SUBROUTINE PERFORMS RUNGE KUTTA FOR PASSIVE DENDRITIC MEMBRANE.
  495 CALL WXR92C (VBZ,BB,BC,
     1  KT,  DELT,NSTEP,HAFDEL,DELSIX,KRTEST,
     2 NZ,NLZ,JS,JH,JT,UA,UD,USA,USD,
     3 RACT,RINB,RINC,QENCHA,ROUTB,ROUTC,QENCHB,AFPOS)                MAINPRO
  500 KT = KT + 1                                                    WXR701C
  510 GO TO 370
  520 KVE = 0
      CALL NIH104 (ICLOCK,JCLOCK)
      WRITE OUTPUT TAPE 15,999, JCLOCK
  530 WRITE OUTPUT TAPE 15, 901                                      WXR701C
  531 IF(IFAB) 532,532,536
  532 WRITE OUTPUT TAPE 15, 926, PROBNO, (JZ, JZ=1,NZ)
  926 FORMAT (11HVATZ(KT,JZ) 90X, 8HPROBNO., F10.4 //
     X                     3H KT, 2X,3HJZ=,  14(I6,2X,)/)
  533 DO 534 KT=1, NT
  534 WRITE OUTPUT TAPE 15, 956, KT, (VATZ(KT,JZ), JZ=1, NZ)
```

```
 956 FORMAT (I3, 5X, 14(1X,F7.4))
 535 WRITE OUTPUT TAPE 15, 904
 536 IF(IFAB) 560,538,538
 538 WRITE OUTPUT TAPE 15, 927, PROBNO, (JZ, JZ=1,NZ)
 927 FORMAT (11HVBTZ(KT,JZ) 90X, 8HPROBNO., F10.4 //
   X                          3H KT, 2X,3HJZ=,  14(I6,2X,)/)
 540 DO 550 KT=1,NT
 550 WRITE OUTPUT TAPE 15, 956, KT, (VBTZ(KT,JZ), JZ=1, NZ)
 560 CALL NIH104 (ICLOCK,JCLOCK)
     WRITE OUTPUT TAPE 15,999, JCLOCK
5601 IF(NPLZ) 570,570,561
 561 DO 569 KT=1, MKTPLZ,LKTPLZ
 562 DO 564 JZ=1,NZ
 563 VAP(JZ) = VATZ(KT,JZ)
 564 VBP(JZ) = VBTZ(KT,JZ)
 565 WRITE OUTPUT TAPE 15, 904
 566 WRITE OUTPUT TAPE 15, 945, KT, TK(KT), KVE, PROBNO
 945 FORMAT(58HPLOT OF VALUES VERSUS DISTANCE (JZ AND ZJ), FOR THE CASE
   1, 3HKT=, I3, 4X, 7HTK(KT)=, F5.2, 4X, 4HKVE=, I1, 5X,
   2 16HWXR786C. PROBNO. F10.4 /)
 567 CALL WXR82C (VAP,VBP,VMIN,VMAX,NZ,NSPPLZ,NSKIPZ,ZJ,IFAB,IFHL)
 569 CONTINUE
 570 CALL NIH104 (ICLOCK,JCLOCK)
     WRITE OUTPUT TAPE 15,999, JCLOCK
 571 IF(NPLT) 580,660,580
 580 DO 650 JZ=LJZPLT,MJZPLT,LJZPLT
 587 WRITE OUTPUT TAPE 15, 901
 590 WRITE OUTPUT TAPE 15, 946, JZ, ZJ(JZ), KVE, PROBNO
 946 FORMAT(54HPLOT OF VALUES VERSUS TIME (KT AND TK), FOR THE CASE,
   1 3HJZ=, I2, 5X, 7HZJ(JZ)=, F5.2, 4X, 4HKVE=, I1, 9X,
   2 16HWXR786C. PROBNO. F10.4 /)
 600 IF(IFAB) 610,610,625
 610 DO 620 KT=1,NT
 620 VAP(KT) = VATZ(KT,JZ)
 625 IF(IFAB) 640,626,626
 626 DO 630 KT=1,NT
 630 VBP(KT) = VBTZ(KT,JZ)
 640 CALL WXR82C (VAP,VBP,VMIN,VMAX,NT,NSPPLT,NSKIPT,TK,IFAB,IFHL)
     CALL NIH104 (ICLOCK,JCLOCK)
     WRITE OUTPUT TAPE 15,999, JCLOCK
 650 CONTINUE
 660 IF(IFVE) 800,800,661
 661 KVE = KVE + 1
 662 WRITE OUTPUT TAPE 15, 901
 663 GO TO (700,750,800), KVE
 700 WRITE OUTPUT TAPE 15, 701
 701 FORMAT (47HFOLLOWING CORRESPOND TO ZERO SHUNT CONDUCTANCE.  /)
 702 VMAX = 3.
 703 VMIN = -2.5
 704 IF(IFAB) 705,705,714
 705 DO 712 KT=1,NT
 706 PA = VATZ(KT,NZ)
 707 DO 708 JZ=1,NZ
```

```
  708 VATZ(KT,JZ) =-2.5*(VATZ(KT,JZ) - PA)
  709 PA = VATZ(KT,JS)
  710 DO 711 JZ=1,JH
  711 VATZ(KT,JZ) = CORE*(VATZ(KT,JZ) - PA)  + PA
  712 CONTINUE
  714 IF(IFAB) 531,715,715
  715 DO 722 KT=1,NT
  716 PB = VBTZ(KT,NZ)
  717 DO 718 JZ=1,NZ
  718 VBTZ(KT,JZ) =-2.5*(VBTZ(KT,JZ) - PB)
  719 PB = VBTZ(KT,JS)
  720 DO 721 JZ=1,JH
  721 VBTZ(KT,JZ) = CORE*(VBTZ(KT,JZ) - PB)  + PB
  722 CONTINUE
  725 GO TO 531
  750 WRITE OUTPUT TAPE 15, 751
  751 FORMAT(53HFOLLOWING CORRESPONDS TO SHUNT WITH FACTOR 0.25     /)
  752 DO 780 KT=1, NT
  753 PA = VATZ(KT,1)
  754 PB = VBTZ(KT,1)
  759 IF(IFAB) 760,760,769
  760 IF(ABSF(PA) - .001) 769,761,761
  761 DA = -.2*PA
  762 DO 763 JZ=1, NZ
  763 VATZ(KT,JZ) = VATZ(KT,JZ) + DA
  769 IF(IFAB) 780,770,770
  770 IF(ABSF(PB) - .001) 780,771,771
  771 DB = -.2*PB
  772 DO 773 JZ=1, NZ
  773 VBTZ(KT,JZ) = VBTZ(KT,JZ) + DB
  780 CONTINUE
  783 GO TO 531
  800 WRITE OUTPUT TAPE 15, 904
  810 WRITE OUTPUT TAPE 15, 908
  908 FORMAT (28HREAD INPUT FOR NEXT PROBLEM. //)                        WXR701C
  815 WRITE OUTPUT TAPE 15, 901
  820 GO TO 140
      END                                                                WXR701C

      SUBROUTINE WXR82C(VA,VB,VMIN,VMAX,NPLP,NSPACE,NSKIP,ABSCIS,IFPLAB,
     X IFHL)
C
C     2.4.64  ADDED  2042 2112 2222 2262 2422 2462.
C     1.15.64      1.16.64
C      1.10.64 BLEND OF WXR80C AND WXR81C.  1.13.64
C     1.2.64  MODIFIED AND SIMPLIFIED PLOT ROUTINE.
C
      DIMENSION VA(251),VB(251),ABSCIS(251),SCALE(12),SORD(111)
C
C     SORD(111) IS A VARIABLE WHICH PERMITS SPECIFICATION OF SYMBOLS TO BE
C     ENTERRED IN THE 111 ALPHANUMERIC FIELDS OF UNIT SIZE, (111A1).
C
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C      FOLLOWING ARGUS STATEMENTS DEFINE VARIABLES AS PRINTER SYMBOLS.
ASYMA      ALF         A
ASYMB      ALF         B
ASYMC      ALF         C
ASYMX      ALF         X
ASYMY      ALF         Y
ASYMZ      ALF         Z
ASYMO      ALF         0
ASYMPL     ALF         +
ASYMBL     ALF
C
  120 WRITE OUTPUT TAPE 15, 902
  902 FORMAT(13HVA SHOWN (A). 2X, 13HVB SHOWN (B). 2X, 22HCOINCIDENCE SH
     XOWN (C). 2X, 53HSCALE SHIFT INDICATED BY SUBST. (X,Y,Z. FOR (A,B,C
     X).  4X, 7HWXR82C. /)
C
  570 KPLAB = 2 + IFPLAB
  575 KDK = 1 + NSKIP
  580 IF(NSPACE) 581,581,582
  581 NSPACE = 1
  582 JSPACE = NSPACE - 1
  584 PRANGE =110./(VMAX - VMIN)
  585 LZERO= 1.5 + PRANGE*(-VMIN)
  586 DSCALE = (VMAX-VMIN)/11.
  587 SCALE(1) = VMIN
  588 DO 589 J=2,12
  589 SCALE(J) = SCALE(J-1) + DSCALE
  130 WRITE OUTPUT TAPE 15, 903, (SCALE(J), J=1,12)
C 130 THIS LABELS ORDINATE SCALE
  903 FORMAT (6HSCALES /          12(3X, F7.2) /  9X, 1H+, 11(9X, 1H+))
  140 KT = 1
  180 DO 190 J=1,111
  190 SORD(J) = SYMPL
  191 SORD(LZERO) = SYMO
  195 GO TO (220,200,240), KPLAB
  200 JA = 1.5 + PRANGE*(VA(KT) - VMIN)
  201 JB = 1.5 + PRANGE*(VB(KT) - VMIN)
  202 IF(JA-JB) 221,203,221
  203 IF(JA-1) 204,215,210
  204 JA = JA + 110
 2041 IF(JA-1) 2042,205,205
 2042 JA = 1
  205 SORD(JA) = SYMZ
  206 GO TO 400
  210 IF(JA-111) 215,215,211
  211 JA = JA - 110
 2111 IF(JA-111) 212,212,2112
 2112 JA = 110
  212 SORD(JA) = SYMZ
  213 GO TO 400
  215 SORD(JA) = SYMC
  216 GO TO 400
  220 JA = 1.5 + PRANGE*(VA(KT) - VMIN)
```

```
  221 IF(JA-1) 222,230,225
  222 JA = JA + 110
 2221 IF(JA-1) 2222,223,223
 2222 JA = 1
  223 SORD(JA) = SYMX
  224 GO TO 231
  225 IF(JA-111) 230,230,226
  226 JA = JA -110
 2261 IF(JA-111) 227,227,2262
 2262 JA = 110
  227 SORD(JA) = SYMX
  228 GO TO 231
  230 SORD(JA) = SYMA
  231 GO TO (400,241,240),KPLAB
  240 JB = 1.5 + PRANGE*(VB(KT) - VMIN)
  241 IF(JB-1) 242,250,245
  242 JB = JB + 110
 2421 IF(JB-1) 2422,243,243
 2422 JB = 1
  243 SORD(JB) = SYMY
  244 GO TO 400
  245 IF(JB-111) 250,250,246
  246 JB = JB - 110
 2461 IF(JB-111) 247,247,2462
 2462 JB = 110
  247 SORD(JB) = SYMY
  248 GO TO 400
  250 SORD(JB) = SYMB
  400 WRITE OUTPUT TAPE 15, 940, KT, ABSCIS(KT), (SORD(J), J=1,111)
  940 FORMAT (I3, 1X, F4.2, 1X, 111A1)
  401 KT = KT + KDK
  402 IF(KT - NPLP) 405,425,500
  405 IF(IFHL) 410,410,420
  410 DO 411 J=1,111
  411 SORD(J) = SYMBL
  412 SORD(1) = SYMPL
  413 SORD(111) = SYMPL
  414 GO TO 430
  420 DO 421 J=1,111
  421 SORD(J) = SYMBL
  422 DO 423 J=1,111,10
  423 SORD(J) = SYMPL
  424 GO TO 430
  425 DO 426 J=1,111
  426 SORD(J) = SYMPL
  430 SORD(LZERO) = SYMO
  431 IF(JSPACE)195,195,432
  432 KSPACE = JSPACE
  440 WRITE OUTPUT TAPE 15, 950
  950 FORMAT(9X, 1H+, 109X, 1H+)
C       THIS ADVANCES ABSCISSA BY ONE PRINTER LINE WHEN KSPACE IS ONE OR
  460 KSPACE = KSPACE - 1
  470 IF(KSPACE) 195,195,440
```

```
  500 RETURN
      END

      SUBROUTINE WXR91C (QK,QB,QC,
     1  KT,  DELT,NSTEP,HAFDEL,DELSIX,KRTEST,
     2 NZ,NLZ,JS,JH,JT,GA,GD,GSA,GSD,
     3 RACT,RINB,RINC,QUENCH,ROUTB,ROUTC,QENCHB,AFPOS)
C
C       1.21.64 CORRECTED STATEMENT 453            MOD OF WXR85C
C      1.7.64    1.8.64
C      12.31.63  ADDITION OF AFPOS.
C      12.18.63          THIS IS CUBED VERSION.
C      12.18.63  MOD OF WXR81 AND 83C.
C      12.14.63  MOD OF WXR81C
C      12.9.63       12.12.63  454-468)
C      12.5.63  MOD OF 79C.
C      RUNGE KUTTA FOR ACTIVE DENDRITES.
C
       DIMENSION QK(14),QB(14),QC(14),A(14),B(14),C(14),DQ(14,4),
     X DB(14,4),DC(14,4)
C
       RINC = RINC
C    THIS STATEMENTS IS TO SATISFY ARGUMENT.  RINC   IS NO LONGER USED BY PROGRAM
  400 JSTEP = 0
  406 IF(KRTEST) 410,410,407
  407 WRITE OUTPUT TAPE 15, 408, KT
  408 FORMAT (5X, 3HKT=, I3, 65X, 25HTEST PRINT WITHIN WXR91C. )
  410 JR=0
  420 DO 430 JZ=1, NZ
  428 B(JZ) = QB(JZ)
  429 C(JZ) = QC(JZ)
  430 A(JZ) = QK(JZ)
  440 IF(KRTEST) 445,445,441
  441 WRITE OUTPUT TAPE 15, 941, JR, JSTEP
  941 FORMAT (24HARGUMENTS A,B,C FOR JR=  ,I1, 5X, 6HJSTEP=, I3)
  942 FORMAT (5X, 10E10.3 )
  442 WRITE OUTPUT TAPE 15, 942, (A(JZ), JZ=1, NZ)
  443 WRITE OUTPUT TAPE 15, 942, (B(JZ), JZ=1, NZ)
  444 WRITE OUTPUT TAPE 15, 942, (C(JZ), JZ=1, NZ)
  445 JR = JR + 1
  451 DQ(1,JR) =GA*(A(2)-A(1))-A(1)+RACT*B(1)*(1.0-A(1)) -
     X QUENCH*C(1)*(A(1)+AFPOS)                                       451X
  452 DQ(NZ,JR) =GD*(A(NLZ)-A(NZ)) - A(NZ) + RACT*B(NZ)*(1.0-A(NZ)) -
     X QUENCH*C(NZ)*(A(NZ)+AFPOS)                                     452X
  453 DQ(JS,JR) = GSD*(A(JT)-A(JS)) + GSA*(A(JH)-A(JS)) - A(JS) +     1.21.64
     X RACT*B(JS)*(1.-A(JS)) - QUENCH*C(JS)*(A(JS) + AFPOS)           453X
  454 DO 468 JZ=1,NZ
  455 ATEST = A(JZ) - .001
  456 IF(ATEST) 457,457,464
  457 ACUBE = 0.
  459 BTEST = B(JZ) - .0001
  460 IF(BTEST) 461,461,465
```

```
461 DB(JZ,JR) = -B(JZ)*ROUTB
462 DC(JZ,JR) = -C(JZ)*ROUTC
463 GO TO 468
464 ACUBE = A(JZ)*A(JZ)*A(JZ)
465 BTOC = B(JZ)*(ROUTB + C(JZ)*QENCHB)
466 DB(JZ,JR) = RINB*ACUBE - BTOC
467 DC(JZ,JR) = BTOC - ROUTC*C(JZ)
468 CONTINUE
470 DO 471 JZ=2,JH
471 DQ(JZ,JR) =GA*(A(JZ-1)+A(JZ+1)-A(JZ)-A(JZ)) - A(JZ) + RACT*B(JZ)*    471X
   X (1.0-A(JZ)) - QUENCH*C(JZ)*(A(JZ)+ AFPOS)
472 DO 473 JZ=JT,NLZ
473 DQ(JZ,JR) =GD*(A(JZ-1)+A(JZ+1)-A(JZ)-A(JZ)) - A(JZ) + RACT*B(JZ)*    473X
   X (1.0-A(JZ)) - QUENCH*C(JZ)*(A(JZ)+ AFPOS)
481 IF(KRTEST) 490,490,482
482 WRITE OUTPUT TAPE 15, 982, JR
483 WRITE OUTPUT TAPE 15, 983, (DQ(JZ,JR), JZ=1, NZ)
484 WRITE OUTPUT TAPE 15, 983, (DB(JZ,JR), JZ=1, NZ)
485 WRITE OUTPUT TAPE 15, 983, (DC(JZ,JR), JZ=1, NZ)
982 FORMAT (28HRUNGE-KUTTA DERIVATIVES. JR=, I1)
983 FORMAT (7X, 10E10.3 )
490 GO TO (500,500,530,560), JR
500 DO 510 JZ=1, NZ
508 B(JZ) = QB(JZ) + HAFDEL*DB(JZ,JR)
509 C(JZ) = QC(JZ) + HAFDEL*DC(JZ,JR)
510 A(JZ) = QK(JZ) + HAFDEL*DQ(JZ,JR)
520 GO TO 440
530 DO 540 JZ=1, NZ
538 B(JZ)=QB(JZ) + DELT*DB(JZ,3)
539 C(JZ)=QC(JZ) + DELT*DC(JZ,3)
540 A(JZ)=QK(JZ) + DELT*DQ(JZ,3)
550 GO TO 440
560 DO 570 JZ=1, NZ                                                     WXR71C
568 QB(JZ)=QB(JZ)+(DB(JZ,1)+DB(JZ,4)+(DB(JZ,2)+DB(JZ,3))*2.)*DELSIX
569 QC(JZ)=QC(JZ)+(DC(JZ,1)+DC(JZ,4)+(DC(JZ,2)+DC(JZ,3))*2.)*DELSIX
570 QK(JZ)=QK(JZ)+(DQ(JZ,1)+DQ(JZ,4)+(DQ(JZ,2)+DQ(JZ,3))*2.)*DELSIX
580 JSTEP = JSTEP + 1
581 IF(KRTEST)590,590,582
582 WRITE OUTPUT TAPE 15, 583, JSTEP, (QK(JZ), JZ=1, NZ)
583 FORMAT (27HVALUES OF  VAZ   FOR JSTEP=, I1, / 4X, 14(1X, F7.4))
584 WRITE OUTPUT TAPE 15, 586, (QB(JZ), JZ=1,NZ)
585 WRITE OUTPUT TAPE 15, 587, (QC(JZ), JZ=1,NZ)
586 FORMAT (2X, 2HQB, 2X, 14(1X, F7.4))
587 FORMAT (2X, 2HQC, 2X, 14(1X, F7.4)//)
590 IF(JSTEP - NSTEP) 410,600,600                                       WXR71C
600 RETURN
    END

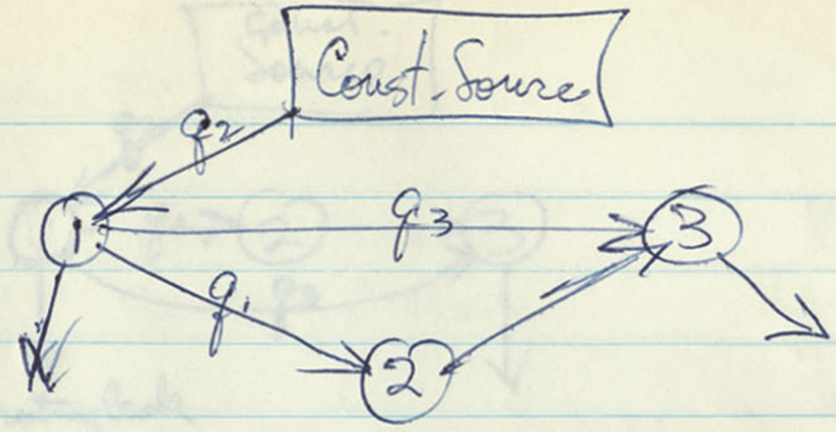
    SUBROUTINE WXR92C (QK,QB,QC,
   1  KT,  DELT,NSTEP,HAFDEL,DELSIX,KRTEST,
   2 NZ,NLZ,JS,JH,JT,GA,GD,GSA,GSD,
   3 RACT,RINB,RINC,QUENCH,ROUTB,ROUTC,QENCHB,AFPOS)
```

```
C
C        1.21.64 CORRECTED STATEMENT 453                          MOD OF WXR86C
C       1.7.64        1.14.64 TO MATCH 85C AS OF 1.8.64
C       12.31.63  ADDITION OF AFPOS.
C       12.20.63   REPAIRED AT 452
C       12.18.63         THIS IS CUBED VERSION.
C       12.18.63  MOD OF WXR82 AND 84C.
C       12.14.63  MOD OF WXR82C
C       12.9.63 12.11.63  12.12.63
C       12.5.63  MOD OF 79C.
C
C THIS IS RUNGE-KUTTA COMPUTATION FOR PASSIVE DENDRITES.
C
        DIMENSION QK(14),QB(14),QC(14),A(14),B(14),C(14),DQ(14,4),
       X DB(14,4),DC(14,4)
C
        RINC = RINC
  400 JSTEP = 0                                                         WXR71C
  402 EQJ = -.1
  406 IF(KRTEST) 410,410,407                                            WXR701C
  407 WRITE OUTPUT TAPE 15, 408, KT
  408 FORMAT (5X, 3HKT=, I3, 65X, 25HTEST PRINT WITHIN WXR92C. )
  410 JR=0                                                              WXR71C
  420 DO 430 JZ=1, NZ                                                   WXR71C
  428 B(JZ) = QB(JZ)
  429 C(JZ) = QC(JZ)
  430 A(JZ) = QK(JZ)                                                    WXR71C
  440 IF(KRTEST) 445,445,441
  441 WRITE OUTPUT TAPE 15, 941, JR, JSTEP
  941 FORMAT (24HARGUMENTS A,B,C FOR JR=  ,I1, 5X, 6HJSTEP=, I3)
  942 FORMAT (5X, 10E10.3 )
  442 WRITE OUTPUT TAPE 15, 942, (A(JZ), JZ=1, NZ)
  443 WRITE OUTPUT TAPE 15, 942, (B(JZ), JZ=1, NZ)
  444 WRITE OUTPUT TAPE 15, 942, (C(JZ), JZ=1, NZ)
  445 JR = JR + 1
  451 DQ(1,JR) =GA*(A(2)-A(1))-A(1)+RACT*B(1)*(1.0-A(1)) -
     X QUENCH*C(1)*(A(1)+AFPOS)                                          451X
  452 DQ(NZ,JR) =GD*(A(NLZ)-A(NZ)) - A(NZ) +
     X B(NZ)*(1.-A(NZ))+ C(NZ)*(EQJ -A(NZ))                              452X
  453 DQ(JS,JR) = GSD*(A(JT)-A(JS)) + GSA*(A(JH)-A(JS)) - A(JS) +        1.21.64
     X RACT*B(JS)*(1.-A(JS)) - QUENCH*C(JS)*(A(JS) + AFPOS)              453X
  454 DO 468 JZ=1,JS
  455 ATEST = A(JZ) - .001
  456 IF(ATEST) 457,457,464
  457 ACUBE = 0.
  459 BTEST = B(JZ) - .0001
  460 IF(BTEST) 461,461,465
  461 DB(JZ,JR) = -B(JZ)*ROUTB
  462 DC(JZ,JR) = -C(JZ)*ROUTC
  463 GO TO 468
  464 ACUBE = A(JZ)*A(JZ)*A(JZ)
  465 BTOC = B(JZ)*(ROUTB + C(JZ)*QENCHB)
  466 DB(JZ,JR) = RINB*ACUBE - BTOC
```

```
  467 DC(JZ,JR) = BTOC - ROUTC*C(JZ)
  468 CONTINUE
  470 DO 4702 JZ=JT,NZ
 4701 DB(JZ,JR) = 0.
 4702 DC(JZ,JR) = 0.
 4703 DO 471 JZ=JT,NLZ
  471 DQ(JZ,JR) =GD*(A(JZ-1)+A(JZ+1)-A(JZ)-A(JZ)) - A(JZ)                       WXR71C
     X + B(JZ)*(1.-A(JZ)) + C(JZ)*(EQJ -A(JZ))                                 471X
C     HERE B AND C CORRESPOND TO  SYNAPTIC E AND J.
  472 DO 473 JZ=2,JH
  473 DQ(JZ,JR) =GA*(A(JZ-1)+A(JZ+1)-A(JZ)-A(JZ)) - A(JZ) + RACT*B(JZ)*
     X (1.0-A(JZ)) - QUENCH*C(JZ)*(A(JZ)+ AFPOS)                               473X
  481 IF(KRTEST) 490,490,482
  482 WRITE OUTPUT TAPE 15, 982, JR
  483 WRITE OUTPUT TAPE 15, 983, (DQ(JZ,JR), JZ=1, NZ)
  484 WRITE OUTPUT TAPE 15, 983, (DB(JZ,JR), JZ=1, NZ)
  485 WRITE OUTPUT TAPE 15, 983, (DC(JZ,JR), JZ=1, NZ)
  982 FORMAT (28HRUNGE-KUTTA DERIVATIVES. JR=, I1)
  983 FORMAT (7X, 10E10.3 )
  490 GO TO (500,500,530,560), JR                                              WXR71C
  500 DO 501 JZ=1, NZ
  501 A(JZ) = QK(JZ) + HAFDEL*DQ(JZ,JR)
  502 DO 509 JZ=1,JS
  508 B(JZ) = QB(JZ) + HAFDEL*DB(JZ,JR)
  509 C(JZ) = QC(JZ) + HAFDEL*DC(JZ,JR)
  520 GO TO 440                                                                WXR71C
  530 DO 531 JZ=1, NZ
  531 A(JZ)=QK(JZ) + DELT*DQ(JZ,3)
  532 DO 539 JZ=1,JS
  538 B(JZ)=QB(JZ) + DELT*DB(JZ,3)
  539 C(JZ)=QC(JZ) + DELT*DC(JZ,3)
  550 GO TO 440                                                                WXR71C
  560 DO 561 JZ=1, NZ
  561 QK(JZ)=QK(JZ)+(DQ(JZ,1)+DQ(JZ,4)+(DQ(JZ,2)+DQ(JZ,3))*2.)*DELSIX
  562 DO 569 JZ=1,JS
  568 QB(JZ)=QB(JZ)+(DB(JZ,1)+DB(JZ,4)+(DB(JZ,2)+DB(JZ,3))*2.)*DELSIX
  569 QC(JZ)=QC(JZ)+(DC(JZ,1)+DC(JZ,4)+(DC(JZ,2)+DC(JZ,3))*2.)*DELSIX
  580 JSTEP = JSTEP + 1                                                        WXR71C
  581 IF(KRTEST)590,590,582
  582 WRITE OUTPUT TAPE 15, 583, JSTEP, (QK(JZ), JZ=1, NZ)
  583 FORMAT (27HVALUES OF  VBZ   FOR JSTEP=, I1, / 4X, 14(1X, F7.4))
  584 WRITE OUTPUT TAPE 15, 586, (QB(JZ), JZ=1,NZ)
  585 WRITE OUTPUT TAPE 15, 587, (QC(JZ), JZ=1,NZ)
  586 FORMAT (2X, 2HQB, 2X, 14(1X, F7.4))
  587 FORMAT (2X, 2HQC, 2X, 14(1X, F7.4)//)
  590 IF(JSTEP - NSTEP) 410,600,600                                            WXR71C
  600 RETURN                                                                   WXR71C
      END                                                                      WXR71C
```

Equations

7/19/63



$$k_{14} = \lambda_{14} q_4$$

$$\dot{q}_1 = k_{14} q_2 - \lambda_{01} q_1 - \lambda_{21} (q_1)^2 - \lambda_{31} q_3 q_1$$

negligible when $q_1 <$ thresh

not quite neglig. for $q_3 > 0$ rel effect.

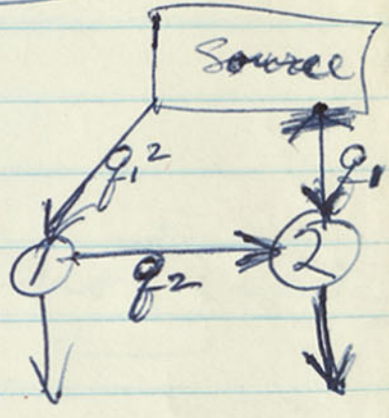
$$\dot{q}_2 = \lambda_{21} (q_1)^2 - \lambda_{32} q_2$$

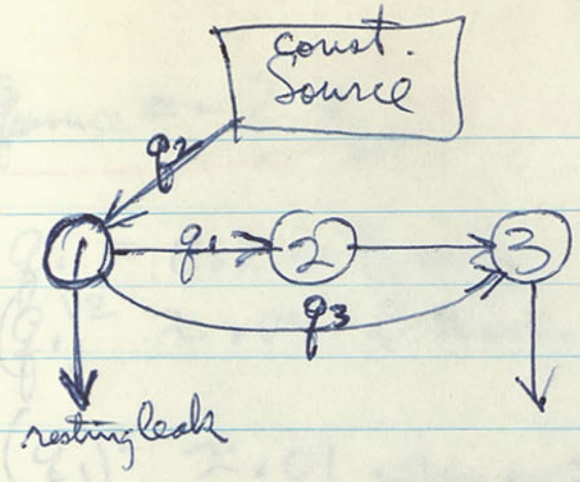
$$\dot{q}_3 = \lambda_{32} q_2 + \lambda_{31} q_1 q_3 - \lambda_{03} q_3$$

Simplest system probably is following

$$\dot{q}_1 = k_{1S} q_1^2 - \lambda_{01} q_1 - \lambda_{21} q_1 q_2$$

$$\dot{q}_2 = k_{2S} q_1 + \lambda_{21} q_1 q_2 - \lambda_{02} q_2$$



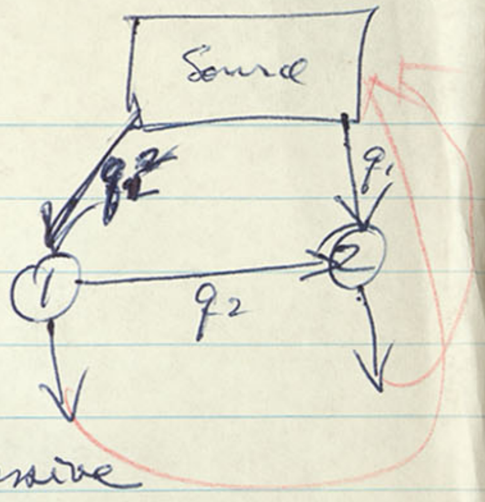


One could dispense with ② if one ~~created~~ defines a threshold in the program

then, for q_1 > thresh, have flow from source prop. to q_1

& start charging ③

$\lambda_{source} = -\sum_i \lambda_{is}$ or



If $q_1 = 0.2$ is thresh
$(q_1)^2 \approx .04$ at thresh.

$(q_1)^2 \approx .01$ when essentially passive

$\therefore$ want $[\lambda_{1s} q_s] \approx 5.$

for $\lambda_{01} = 1$

Also, want $[\lambda_{2s} q_s] \approx 0.5$

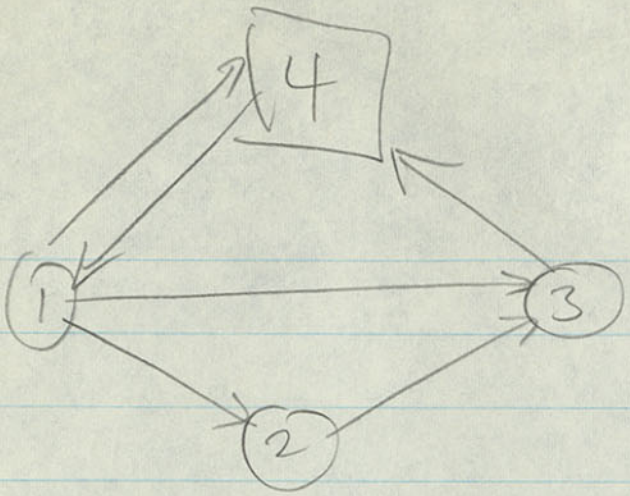
$\lambda_{02} \approx 2.$?

$(\lambda_{21} \times 1. \times q_2) \gg 5.$

but λ_{21} *

But Moores' program does not easily give $\lambda_{1s} \propto q_1^2$ without additional cpts.

7/24/63



except that ~~it is~~ they are not reversible, λ_{14} corresponds to G_E
λ_{41} corresp to G_r
λ_{31} corresp to G_j

and q_2 & q_3 serve as auxiliary variables.

Could modify to make reversible, if this seems necessary, but does the exp. evidence really prove it to be reversible? Check back on this. See also recent Tasaki paper.

Also, can make a particular $\lambda = k_1 + k_2 q_j$ by means of dummies & dependence relations.

Perhaps yes in the sense of equilibrium potential s_g exp. max. spike amplitude

1/27/64 Outline Summary of 64791. series so far

see p. 67 of notebook

	VA	VD	USA	USD	RINB	QCHA	ROUTB	ROUTC	QCHB		Soma Block Act	Pass	Reflected Orthodromic spike Act.	Pass.	Comments
.0111	8.	16.	4.	32.	20.	20.	40.	2.	60.	 ampl. KT	blk .15 41	blk .15 41	———		Good spike shape. ~~Hillock~~ spike falls most sharply because less back spread.
.0211	"	"	"	"	"	"	20.	3.	60.	 ampl KT	n.bl. .94 62	n.bl. .85 80	no	yes	Significant delay of soma spike in case of passive dendrites. ∴ Hilloc was less refractory to reflected orthodrom
.0411	"	32.	"	64.	"	"	"	"	"	 ampl. KT	~~n.bl.~~ .96 111	blk .12 37	yes	no	Very long soma delay. Peripheral dendritic spike occurred before soma. Must have been very near threshold.
.0511	"	"	8.	128.	"	"	"	"	"		~~n.bl.~~ .96 111	blk .12 35	yes	no	Almost identical with above (.0411) ~~.0411~~, showing that ratio, USD/USA matters more than abs. vol.
.0112	8.	32.	1.	64.	20.	"	40.	2.	60.		blk	blk	———		Soma peak = .0273 in both cases
.0312	"	"	"	"	30.	"	20.	3.	"		blk	blk	———		hotter axonal spike soma Same as .0112; just passive electrot.
.0412	"	"	2.	"	50.	"	"	"	"		blk	blk	———		hotter; soma peak = .048
.0512	"	"	4.	128.	"	"	"	"	"		blk	blk	———		Same; .054 also evidence for USD/USA ratio
.0113	8.	32.	1.	32.	20.	"	40.	2.	60.		blk	blk	———		Soma peak = .045
.0313	"	"	"	"	30.	"	20.	3.	60.		blk	blk	———		.044
.0413	"	"	2.	"	50.	"	"	"	"	 ampl. KT	n.bl. .97 82	blk .081 26	yes	no	slightly weaker ~~[illegible]~~ than .0211 slightly stronger than .0412 .0313 Dendritic spike nearly synchronous with soma
~~.0573~~	~~"~~	~~"~~	~~8.~~	~~128.~~	~~"~~	~~40.~~	~~"~~	~~"~~	~~"~~						
.0573	"	"	8.	128.	"	40.	"	"	"	 ampl KT	n.bl. .96 132	 .10 23.	yes	no	periph. dendriz. spike occurred before soma spike.
.0612	same as .0512 except for I.C. = .05 in ④ → ⑨										mbl KT=35		no	no	residual facilitation worked. Short latency prevented reflected spike
.0613	"		".0513		"	"	"	"	"		32		no	no	also here

11/7/63

707C

```
   TITLEWXR707C
C
C        11.7.63 MOD OF WXR706C.
C        10.18.63    10.21.63
C        10.15.63  MOD OF WXR703C
C
  902 FORMAT (18HOUTPUT OF WXR706C. /
     X 24HDR. W. RALL, EXT. 64325. / 15HBLDG. 31, 9A23.   //
     X 28HRECAP OF INPUT INFORMATION.  ////)
C
C TO SOLVE CHAIN OF COMPARTMENTS AND PLOT.  BOTH ACTIVE AND PASSIVE.    WXR701C
C
C        NZ IS NUMBER OF COMPARTMENTS IN CHAIN.
C        NT IS NUMBER OF TIME POINTS FOR EACH Z VALUE.
C        DZ AND DT ARE INCREMENTS IN Z AND T.
C        VMIN AND VMAX DETERMINE ORDINATE SCALE FOR PLOT.
C        IFTEST=1 YIELDS SOME INTERMEDIATE PRINTING.  IFTEST=2 YIELDS R-K PRINTING.
C        NPLT IS NUMBER OF PLOTS VERSUS TIME.
C        KDZPLT  IS NUMBER OF DZ INCREMENTS FOR Z VALUES OF PLOTS VERSUS T.
C        NSPPLT SPECFIES NUMBER OF PRINTER SPACES PER DT OF PLOT.
C        NGRIDT SPECIFIES NUMBER OF DT PER VERTICAL GRID LINE OF + .
C        NPLZ IS NUMBER OF PLOTS VERSUS LENGTH (Z).
C        KDTPLZ IS NUMBER OF DT INCREMENTS FOR T VALUES OF PLOTS VERSUS Z.
C        NSPPLZ SPECIFIES NUMBER OF PRINTER SPACES PER DZ OF PLOT.
C        NGRIDZ SPECIFIES NUMBER OF DZ PER VERTICAL GRID LINE OF +.
C        USUUALLY  NPLT = 1 + NZ/KDZPLT.
C        USUALLY NPLZ = 1 + NT/KDTPLZ
C        NIZ SPECIFIES NUMBER OF COMPARTMENTS, STARTING FROM ORIGIN, WHICH MUST BE
C        SPECIFIED TO INCLUDE ALL NON-ZERO INITIAL VALUES.
C        VMIN AND VMAX REPRESENT MIN AND MAX VALUES OF ORDINATE SCALE FOR PLOT.
C        VAZ ARE VALUES ALONG Z FOR ACTIVE MEMBRANE, = QK IN 73C.
C        VBZ ARE VALUES ALONG Z FOR PASSIVE MEMBRANE, =QK IN 72C.
C        AB AND AC ARE AUXILIARY VALUES FOR ACTIVE CASE. = QB AND QC IN 73C.
C        VATP(100,10) ARE VALUES SELECTED FOR TIME PLOT FOR ACTIVE MEMBRANE.
C        VBTP(100,10) ARE VALUES SELECTED FOR TIME PLOT FOR PASSIVD MEMBRANE.
C
         DIMENSION VAZ(202),VBZ(202),VAT(202),VBT(202),AB(202),AC(202),
     X VATP(202,10),VBTP(202,10),TK(202),ZJ(202),VI(202),IZP(10)
  900 FORMAT (1H0)                                                      WXR701C
  901 FORMAT (1H1)                                                      WXR701C
  903 FORMAT (22HEND OF WXR706C OUTPUT.)
  904 FORMAT (////)                                                     WXR701C
  120 WRITE OUTPUT TAPE 15, 902                                         WXR701C
  140 READ INPUT TAPE 1,  951,
     X PROBNO,NZ,NT,DZ,DT,VMIN,VMAX,IFTEST
  951 FORMAT (F10.4, 2I10, 4F10.4, I10)
  921 FORMAT(4X, 6HPROBNO, 8X, 2HNZ, 8X, 2HNT, 8X, 2HDZ, 8X, 2HDT, 6X,
```

```
     X 4HVMIN, 6X, 4HVMAX, 4X, 6HIFTEST /)
  141 IF END OF FILE 142,150                                                WXR701C
  142 WRITE OUTPUT TAPE 15, 903                                             WXR701C
  144 STOP                                                                  WXR701C
  150 WRITE OUTPUT TAPE 15, 921                                             WXR701C
  160 WRITE OUTPUT TAPE 15, 951,
     X PROBNO,NZ,NT,DZ,DT,VMIN,VMAX,IFTEST
  161 WRITE OUTPUT TAPE 15,  904
  165 IF(IFTEST-2) 168,166,168
  166 KRTEST = 1
C 166 KRTEST=1 CAUSES TEST PRINT WITHIN KUTTA-RUNGE SUBROUTINES.
  167 GO TO 170
  168 KRTEST = 0
  169 IF(IFTEST-10) 173,173,170
  170 NABC = IFTEST - 10
  171 KNABC = NABC
C 171 THIS IS USED AT 410 FOR SELECTED PRINT.
  172 GO TO 180
  173 NABC = 0
  180 READ INPUT TAPE 1,  952,                                              WXR701C
     X NPLT,KDZPLT,NSPPLT,NGRIDT,NPLZ,KDTPLZ,NSPPLZ,NGRIDZ
  922 FORMAT(6X, 4HNPLT, 4X, 6HKDZPLT, 4X, 6HNSPPLT, 4X, 6HNGRIDT,
     X 6X, 4HNPLZ, 4X, 6HKDTPLZ, 4X, 6HNSPPLZ, 4X, 6HNGRIDZ /)
  952 FORMAT (8I10)
  190 WRITE OUTPUT TAPE 15, 922                                             WXR701C
  200 WRITE OUTPUT TAPE 15, 952,                                            WXR701C
     X NPLT,KDZPLT,NSPPLT,NGRIDT,NPLZ,KDTPLZ,NSPPLZ,NGRIDZ
  210 WRITE OUTPUT TAPE 15,  904                                            WXR701C
  220 READ INPUT TAPE 1,                                                    WXR701C
     X 953, NIZ, (VI(IZ), IZ=1,14)
  953 FORMAT (I5, 2X, 14F5.2)
  230 WRITE OUTPUT TAPE 15, 923                                             WXR701C
  923 FORMAT (36HSPECIFICATION OF NIZ INITIAL VALUES. /)                    WXR701C
  240 WRITE OUTPUT TAPE 15,                                                 WXR701C
     X 953, NIZ, (VI(IZ), IZ=1,14)
 2400 KNIZ = NIZ - 14
 2401 JA = 1
 2402 JB = 14
 2403 IF(KNIZ) 241,241,2405
 2405 JA = JA + 14
 2406 JB = JB + 14
 2407 READ INPUT TAPE 1, 953,
     X MIZ, (VI(IZ), IZ=JA,JB)
 2408 WRITE OUTPUT TAPE 15, 953,
     XKNIZ, (VI(IZ), IZ=JA,JB)
 2409 KNIZ = KNIZ - 14
 2410 GO TO 2403
```

```
  241 WRITE OUTPUT TAPE 15, 904
  242 READ INPUT TAPE 1,
     X955, PROGNO, RACT,RINB,RINC,QUENCH,ROUTB,ROUTC
  955 FORMAT (A8, 2X, 6F10.5)
  925 FORMAT (16X, 4HRACT, 6X, 4HRINB, 6X, 4HRINC, 4X, 6HQUENCH, 5X,
     X 5HROUTB, 5X, 5HROUTC  /)
  243 WRITE OUTPUT TAPE 15, 925
  244 WRITE OUTPUT TAPE 15,
     X 955, PROGNO, RACT,RINB,RINC,QUENCH,ROUTB,ROUTC
  245 WRITE OUTPUT TAPE 15,  904
C 250 HERE GENERATE T VALUES, BEGINNING WITH ZERO.
  250 TK(1) = 0.
  260 DO 270 KT=2,NT
  270 TK(KT) = TK(KT-1) + DT
  280 ZJ(1) = .5*DZ
  281 DO 282 JZ=2, NZ
  282 ZJ(JZ) = ZJ(JZ-1) + DZ
  283 JZ = 0
  284 IZP(1) = 1
  285 DO 287 JP=2,NPLT
  286 JZ = JZ + KDZPLT
  287 IZP(JP) = JZ
C 290 HERE G CORRESPONDS TO LAMBDA I-J.
  290 G = 1./(DZ*DZ)                                                 WXR701C
C 300 HERE COMPUTE RUNGE KUTTA STEP SIZE (DELT).
  301 TWOJJ = 4.*G + .1*RACT + 2. + .4*QUENCH
  310 NSTEP = TWOJJ*DT + .5
  311 IF(NSTEP) 312,312,320
  312 NSTEP = 1
  320 XND = NSTEP                                                    WXR701C
  330 DELT = DT/XND                                                  WXR701C
  331 HAFDEL = .5*DELT
  332 DELSIX = DELT/6.
  340 NTZSTP = NT*NZ*NSTEP
  341 WRITE OUTPUT TAPE 15, 905, TWOJJ,G,DELT,NSTEP,NTZSTP
  905 FORMAT (15HCOMPUTED VALUES, 5X,5HTWOJJ,9X,1HG,6X,4HDELT,5X,
     X 5HNSTEP, 4X, 6HNTZSTP  // 15X, 3F10.5, 2I10)
 3411 WRITE OUTPUT TAPE 15, 901
 3412 IF(IFTEST-1) 350,350,3413
 3413 WRITE OUTPUT TAPE 15, 906
  906 FORMAT (23HTEST OUTPUT OF WXR706C. // 21HKT, TK(KT), KT=1,NT. //)
  342 WRITE OUTPUT TAPE 15,343, (KT,TK(KT), KT=1,NT)
  343 FORMAT (10(I3,F9.5))
  344 WRITE OUTPUT TAPE 15,907
  907 FORMAT (///21HJZ, ZJ(JZ), JZ=1,NZ. //)
  345 WRITE OUTPUT TAPE 15,343, (JZ, ZJ(JZ), JZ=1,NZ)
  346 WRITE OUTPUT TAPE 15, 901
```

```
    241 WRITE OUTPUT TAPE 15, 904
    242 READ INPUT TAPE 1,
       X955, PROGNO, RACT,RINB,RINC,QUENCH,ROUTB,ROUTC
    955 FORMAT (A8, 2X, 6F10.5)
    925 FORMAT (16X, 4HRACT, 6X, 4HRINB, 6X, 4HRINC, 4X, 6HQUENCH, 5X,
       X 5HROUTB, 5X, 5HROUTC  /)
    243 WRITE OUTPUT TAPE 15, 925
    244 WRITE OUTPUT TAPE 15,
       X 955, PROGNO, RACT,RINB,RINC,QUENCH,ROUTB,ROUTC
    245 WRITE OUTPUT TAPE 15,  904
C   250 HERE GENERATE T VALUES, BEGINNING WITH ZERO.
    250 TK(1) = 0.
    260 DO 270 KT=2,NT
    270 TK(KT) = TK(KT-1) + DT
    280 ZJ(1) = .5*DZ
    281 DO 282 JZ=2, NZ
    282 ZJ(JZ) = ZJ(JZ-1) + DZ
    283 JZ = 0
    284 IZP(1) = 1
    285 DO 287 JP=2,NPLT
    286 JZ = JZ + KDZPLT
    287 IZP(JP) = JZ
C   290 HERE G CORRESPONDS TO LAMBDA I-J.
    290 G = 1./(DZ*DZ)                                                      WXR701C
C   300 HERE COMPUTE RUNGE KUTTA STEP SIZE (DELT).
    301 TWOJJ = 4.*G + .1*RACT + 2. + .4*QUENCH
    310 NSTEP = TWOJJ*DT + .5
    311 IF(NSTEP) 312,312,320
    312 NSTEP = 1
    320 XND = NSTEP                                                         WXR701C
    330 DELT = DT/XND                                                       WXR701C
    331 HAFDEL = .5*DELT
    332 DELSIX = DELT/6.
    340 NTZSTP = NT*NZ*NSTEP
    341 WRITE OUTPUT TAPE 15, 905, TWOJJ,G,DELT,NSTEP,NTZSTP
    905 FORMAT (15HCOMPUTED VALUES, 5X,5HTWOJJ,9X,1HG,6X,4HDELT,5X,
       X 5HNSTEP, 4X, 6HNTZSTP   // 15X, 3F10.5, 2I10)
   3411 WRITE OUTPUT TAPE 15, 901
   3412 IF(IFTEST-1) 350,350,3413
   3413 WRITE OUTPUT TAPE 15, 906
    906 FORMAT (23HTEST OUTPUT OF WXR706C. // 21HKT, TK(KT), KT=1,NT. //)
    342 WRITE OUTPUT TAPE 15,343, (KT,TK(KT), KT=1,NT)
    343 FORMAT (10(I3,F9.5))
    344 WRITE OUTPUT TAPE 15,907
    907 FORMAT (///21HJZ, ZJ(JZ), JZ=1,NZ. //)
    345 WRITE OUTPUT TAPE 15,343, (JZ, ZJ(JZ), JZ=1,NZ)
    346 WRITE OUTPUT TAPE 15, 901
```

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```
  241 WRITE OUTPUT TAPE 15, 904
  242 READ INPUT TAPE 1,
     X955, PROGNO, RACT,RINB,RINC,QUENCH,ROUTB,ROUTC
  955 FORMAT (A8, 2X, 6F10.5)
  925 FORMAT (16X, 4HRACT, 6X, 4HRINB, 6X, 4HRINC, 4X, 6HQUENCH, 5X,
     X 5HROUTB, 5X, 5HROUTC  /)
  243 WRITE OUTPUT TAPE 15, 925
  244 WRITE OUTPUT TAPE 15,
     X 955, PROGNO, RACT,RINB,RINC,QUENCH,ROUTB,ROUTC
  245 WRITE OUTPUT TAPE 15,  904
C 250 HERE GENERATE T VALUES, BEGINNING WITH ZERO.
  250 TK(1) = 0.
  260 DO 270 KT=2,NT
  270 TK(KT) = TK(KT-1) + DT
  280 ZJ(1) = .5*DZ
  281 DO 282 JZ=2, NZ
  282 ZJ(JZ) = ZJ(JZ-1) + DZ
  283 JZ = 0
  284 IZP(1) = 1
  285 DO 287 JP=2,NPLT
  286 JZ = JZ + KDZPLT
  287 IZP(JP) = JZ
C 290 HERE G CORRESPONDS TO LAMBDA I-J.
  290 G = 1./(DZ*DZ)                                                    WXR701C
C 300 HERE COMPUTE RUNGE KUTTA STEP SIZE (DELT).
  301 TWOJJ = 4.*G + .1*RACT + 2. + .4*QUENCH
  310 NSTEP = TWOJJ*DT + .5
  311 IF(NSTEP) 312,312,320
  312 NSTEP = 1
  320 XND = NSTEP                                                       WXR701C
  330 DELT = DT/XND                                                     WXR701C
  331 HAFDEL = .5*DELT
  332 DELSIX = DELT/6.
  340 NTZSTP = NT*NZ*NSTEP
  341 WRITE OUTPUT TAPE 15, 905, TWOJJ,G,DELT,NSTEP,NTZSTP
  905 FORMAT (15HCOMPUTED VALUES, 5X,5HTWOJJ,9X,1HG,6X,4HDELT,5X,
     X 5HNSTEP, 4X, 6HNTZSTP  // 15X, 3F10.5, 2I10)
 3411 WRITE OUTPUT TAPE 15, 901
 3412 IF(IFTEST-1) 350,350,3413
 3413 WRITE OUTPUT TAPE 15, 906
  906 FORMAT (23HTEST OUTPUT OF WXR706C. // 21HKT, TK(KT), KT=1,NT. //)
  342 WRITE OUTPUT TAPE 15,343, (KT,TK(KT), KT=1,NT)
  343 FORMAT (10(I3,F9.5))
  344 WRITE OUTPUT TAPE 15,907
  907 FORMAT (///21HJZ, ZJ(JZ), JZ=1,NZ. //)
  345 WRITE OUTPUT TAPE 15,343, (JZ, ZJ(JZ), JZ=1,NZ)
  346 WRITE OUTPUT TAPE 15, 901
```

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```
    X 4HVMIN, 6X, 4HVMAX, 4X, 6HIFTEST /)
  141 IF END OF FILE 142,150                                          WXR701C
  142 WRITE OUTPUT TAPE 15, 903                                       WXR701C
  144 STOP                                                            WXR701C
  150 WRITE OUTPUT TAPE 15, 921                                       WXR701C
  160 WRITE OUTPUT TAPE 15, 951,
    X PROBNO,NZ,NT,DZ,DT,VMIN,VMAX,IFTEST
  161 WRITE OUTPUT TAPE 15,  904
  165 IF(IFTEST-2) 168,166,168
  166 KRTEST = 1
C 166 KRTEST=1 CAUSES TEST PRINT WITHIN KUTTA-RUNGE SUBROUTINES.
  167 GO TO 170
  168 KRTEST = 0
  169 IF(IFTEST-10) 173,173,170
  170 NABC = IFTEST - 10
  171 KNABC = NABC
C 171 THIS IS USED AT 410 FOR SELECTED PRINT.
  172 GO TO 180
  173 NABC = 0
  180 READ INPUT TAPE 1,  952,                                        WXR701C
    X NPLT,KDZPLT,NSPPLT,NGRIDT,NPLZ,KDTPLZ,NSPPLZ,NGRIDZ
  922 FORMAT(6X, 4HNPLT, 4X, 6HKDZPLT, 4X, 6HNSPPLT, 4X, 6HNGRIDT,
    X 6X, 4HNPLZ, 4X, 6HKDTPLZ, 4X, 6HNSPPLZ, 4X, 6HNGRIDZ /)
  952 FORMAT (8I10)
  190 WRITE OUTPUT TAPE 15,  922                                      WXR701C
  200 WRITE OUTPUT TAPE 15, 952,                                      WXR701C
    X NPLT,KDZPLT,NSPPLT,NGRIDT,NPLZ,KDTPLZ,NSPPLZ,NGRIDZ
  210 WRITE OUTPUT TAPE 15,  904                                      WXR701C
  220 READ INPUT TAPE 1,                                              WXR701C
    X 953, NIZ, (VI(IZ), IZ=1,14)
  953 FORMAT (I5, 2X, 14F5.2)
  230 WRITE OUTPUT TAPE 15, 923                                       WXR701C
  923 FORMAT (36HSPECIFICATION OF NIZ INITIAL VALUES. /)              WXR701C
  240 WRITE OUTPUT TAPE 15,                                           WXR701C
    X 953, NIZ, (VI(IZ), IZ=1,14)
 2400 KNIZ = NIZ - 14
 2401 JA = 1
 2402 JB = 14
 2403 IF(KNIZ) 241,241,2405
 2405 JA = JA + 14
 2406 JB = JB + 14
 2407 READ INPUT TAPE 1, 953,
    X MIZ, (VI(IZ), IZ=JA,JB)
 2408 WRITE OUTPUT TAPE 15, 953,
    XKNIZ, (VI(IZ), IZ=JA,JB)
 2409 KNIZ = KNIZ - 14
 2410 GO TO 2403
```

```
   241 WRITE OUTPUT TAPE 15, 904
   242 READ INPUT TAPE 1,
      X955, PROGNO, RACT,RINB,RINC,QUENCH,ROUTB,ROUTC
   955 FORMAT (A8, 2X, 6F10.5)
   925 FORMAT (16X, 4HRACT, 6X, 4HRINB, 6X, 4HRINC, 4X, 6HQUENCH, 5X,
      X 5HROUTB, 5X, 5HROUTC  /)
   243 WRITE OUTPUT TAPE 15, 925
   244 WRITE OUTPUT TAPE 15,
      X 955, PROGNO, RACT,RINB,RINC,QUENCH,ROUTB,ROUTC
   245 WRITE OUTPUT TAPE 15,  904
C  250 HERE GENERATE T VALUES, BEGINNING WITH ZERO.
   250 TK(1) = 0.
   260 DO 270 KT=2,NT
   270 TK(KT) = TK(KT-1) + DT
   280 ZJ(1) = .5*DZ
   281 DO 282 JZ=2, NZ
   282 ZJ(JZ) = ZJ(JZ-1) + DZ
   283 JZ = 0
   284 IZP(1) = 1
   285 DO 287 JP=2,NPLT
   286 JZ = JZ + KDZPLT
   287 IZP(JP) = JZ
C  290 HERE G CORRESPONDS TO LAMBDA I-J.
   290 G = 1./(DZ*DZ)                                                    WXR701C
C  300 HERE COMPUTE RUNGE KUTTA STEP SIZE (DELT).
   301 TWOJJ = 4.*G + .1*RACT + 2. + .4*QUENCH
   310 NSTEP = TWOJJ*DT + .5
   311 IF(NSTEP) 312,312,320
   312 NSTEP = 1
   320 XND = NSTEP                                                       WXR701C
   330 DELT = DT/XND                                                     WXR701C
   331 HAFDEL = .5*DELT
   332 DELSIX = DELT/6.
   340 NTZSTP = NT*NZ*NSTEP
   341 WRITE OUTPUT TAPE 15, 905, TWOJJ,G,DELT,NSTEP,NTZSTP
   905 FORMAT (15HCOMPUTED VALUES, 5X,5HTWOJJ,9X,1HG,6X,4HDELT,5X,
      X 5HNSTEP, 4X, 6HNTZSTP // 15X, 3F10.5, 2I10)
  3411 WRITE OUTPUT TAPE 15, 901
  3412 IF(IFTEST-1) 350,350,3413
  3413 WRITE OUTPUT TAPE 15, 906
   906 FORMAT (23HTEST OUTPUT OF WXR706C. // 21HKT, TK(KT), KT=1,NT. //)
   342 WRITE OUTPUT TAPE 15,343, (KT,TK(KT), KT=1,NT)
   343 FORMAT (10(I3,F9.5))
   344 WRITE OUTPUT TAPE 15,907
   907 FORMAT (///21HJZ, ZJ(JZ), JZ=1,NZ. //)
   345 WRITE OUTPUT TAPE 15,343, (JZ, ZJ(JZ), JZ=1,NZ)
   346 WRITE OUTPUT TAPE 15, 901
```

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```
   350 KT = 1                                                             WXR701C
   351 JPLZ = 1
   352 KTEST = 1
   353 NP = NPLT
C  360 HERE TO 390 TAKE CARE OF ZERO AND NONZERO INITITIAL CONDITIONS.
   360 DO 370 JZ=1, NZ                                                    WXR701C
   367 AB(JZ) = 0.
   368 AC(JZ) = 0.
   369 VAZ(JZ) = 0.
   370 VBZ(JZ) = 0.
   375 IF(NIZ) 380,376,380                                                WXR701C
   376 WRITE OUTPUT TAPE 15, 377                                          WXR701C
   377 FORMAT (35HINITIAL CONDITIONS MISSING AT 375.  /)                  WXR701C
   378 GO TO 720                                                          WXR701C
   380 DO 390 JZ=1, NIZ                                                   WXR701C
   389 VAZ(JZ) = VI(JZ)
   390 VBZ(JZ) = VI(JZ)
C  410 SEE 169-171.  PRINT ONLY WHEN KT IS A MULTIPLE OF  NABC = IFTEST-10.
   410 IF(NABC) 4250,4250,411
   411 IF(KT-KNABC) 4250,420,412
   412 KNABC = KNABC + NABC
   413 GO TO 411
   420 WRITE OUTPUT TAPE 15, 931, KT, TK(KT)
   931 FORMAT (//3HKT=, I3, 3X, 3HTK=, F7.3, 5X,71HTEST PRINT IN WXR706C
      XOF VAZ(JZ), AB(JZ), AC(JZ), VBZ(JZ) FOR JZ=1,NZ.  /)
   422 WRITE OUTPUT TAPE 15, 942, (VAZ(JZ), JZ=1, NZ)
  4221 WRITE OUTPUT TAPE 15, 942, (AB(JZ), JZ=1,NZ)
  4222 WRITE OUTPUT TAPE 15, 942, (AC(JZ), JZ=1,NZ)
   424 WRITE OUTPUT TAPE 15, 942, (VBZ(JZ), JZ=1, NZ)
   942 FORMAT (10F12.5)
  4250 IF(NPLZ) 430,430,4251
  4251 IF(JPLZ-NPLZ) 4252,4252,430
  4252 IF(KT-KTEST) 430,4260,4255
  4255 KTEST = KTEST + KDTPLZ
  4256 GO TO 4252
  4260 WRITE OUTPUT TAPE 15, 901
  4261 WRITE OUTPUT TAPE 15, 945, KT, TK(KT), PROBNO
   945 FORMAT(58HPLOT OF VALUES VERSUS DISTANCE (JZ AND ZJ), FOR THE CASE
      X, 3HKT=,I3,7X,7HTK(KT)=, F8.4, 8X,  16HWXR706C, PROBNO. F10.4 /)
  4262 CALL WXR76C (VAZ,VBZ,VMIN,VMAX,NZ,NSPPLZ,NGRIDZ,ZJ)
  4263 JPLZ = JPLZ + 1
C  430 HERE SET UP DO LOOP WHICH FORMS VATP FROM VAZ AND VBTP FROM VBZ, FOR KT.
   430 VATP(KT,1)= VAZ(1)
   431 VBTP(KT,1) = VBZ(1)
   440 JZ = 0                                                             WXR701C
   450 DO 470 JP=2, NPLT
   460 JZ= JZ + KDZPLT
```

```
  740 GO TO 140                                                                 WXR701C
      END                                                                       WXR701C
```

76C

```
      SUBROUTINE WXR76C (VA,VB,VMIN,VMAX,NPLP,NSPACE,NGRID,ABSCIS)
C
C     10.15.63  MOD OF WXR75C AND 703C.
C
      DIMENSION VA(202),LA(202),KA(202),VB(202),LB(202),KB(202),SORD(101
     X),ABSCIS(202),SCALE(6)
C
  580 IF(NSPACE) 581,581,584
  581 NSPACE = 1
  584 PRANGE =100./(VMAX - VMIN)
  585 LOJP = 1.5 + PRANGE* (-VMIN)
  595 DO 690 KT =1, NPLP
  586 DSCALE = 0.2*(VMAX - VMIN)
  587 SCALE(1) = VMIN
  588 DO 589 J=2,6
  589 SCALE(J) = SCALE(J-1) + DSCALE
  598 KA(KT) =0
  599 KB(KT) =0
  600 LA(KT) = 1.5 + PRANGE*(VA(KT) - VMIN)
  601 LB(KT) = 1.5 + PRANGE*(VB(KT) - VMIN)
  610 IF(LA(KT) - 1) 611,650,620
  611 VMIN= VA(KT) - DSCALE
  612 GO TO 584
  620 IF(LA(KT) - 101)650,650,621
  621 LA(KT) = LOJP + (LA(KT) - LOJP)/5
  622 KA(KT) = KA(KT) + 1
  623 GO TO 620
  650 IF(LB(KT) - 1) 651,690,660
  651 VMIN= VB(KT) - DSCALE
  652 GO TO 584
  660 IF(LB(KT) - 101) 690,690,661
  661 LB(KT) = LOJP+ (LB(KT) - LOJP)/5
  662 KB(KT) = KB(KT) + 1
  663 GO TO 660
  690 CONTINUE
C     THIS POINT CORRESPONDS TO BEGINNING OF PREVIOUS WXR75C.
C     SORD(101) IS A VARIABLE WHICH PERMITS SPECIFICATION OF SYMBOLS TO BE
C     ENTERRED IN THE 101 ALPHNUMERIC FIELDS OF UNIT SIZE (101A1).
C
C     FOLLOWING ARGUS STATEMENTS DEFINE VARIABLES AS PRINTER SYMBOLS.
ASYMA   ALF         A
ASYMB   ALF         B
ASYMPL  ALF         +
```

```
ASYMBL    ALF
ASYMCO    ALF      O
C
  120 WRITE OUTPUT TAPE 15, 902
  902 FORMAT(13HVA SHOWN (A). 2X, 13HVB SHOWN (B). 2X, 22HCOINCIDENCE SH
     XOWN (O). 2X,    40HRESCALING INDICATED AT TOP BY KA AND KB. 18X,
     X 7HWXR76C. /)
  130 WRITE OUTPUT TAPE 15, 903, (SCALE(J), J=1,6)
C 130 THIS LABELS ORDINATE SCALE
  903 FORMAT (6HSCALES, 6X, F7.3, 5(13X, F7.3) / 15X, 1H+, 5(19X, 1H+),
     X 4HKAKB)
  140 KT = 1
  141 KTEST = 1
  150 IF(NGRID)160,160,200
  160 NGRID = 10
C 200 BEGIN LOOP BY TESTING KT.  FOR KT =1+NGRID*I, DISPLAY VERTICAL LINE OF +.
  200 IF(KT-KTEST) 250,220,210
  210 KTEST = KTEST + NGRID
  211 GO TO 200
  220 DO 230 J=1, 101
  230 SORD(J) = SYMPL
  240 GO TO 320
  250 DO 260 J=1, 101
  260 SORD(J) = SYMBL
  270 DO 280 J=1, 101, 20
  280 SORD(J) = SYMPL
  320 JA = LA(KT)
  330 JB = LB(KT)
  340 IF(JA-JB) 350,380,350
  350 SORD(JA) = SYMA
  360 SORD(JB) = SYMB
  370 GO TO 400
  380 SORD(JA) = SYMCO
  400 WRITE OUTPUT TAPE 15, 940, KT, ABSCIS(KT), (SORD(J), J=1,101),
     X KA(KT), KB(KT)
  940 FORMAT (I3, 1X, F9.4, 2X, 101A1, 2I2)
  410 KT = KT + 1
  420 IF(KT -NPLP)430,430,500
  430 KSPACE = NSPACE - 1
  440 IF(KSPACE) 200,200,450
  450 WRITE OUTPUT TAPE 15, 950
  950 FORMAT (15X, 1H+, 5(19X, 1H+))
C     THIS ADVANCES ABSCISSA BY ONE PRINTER LINE WHEN KSPACE IS ONE OR MORE.
  460 KSPACE = KSPACE - 1
  470 GO TO 440
  500 RETURN
      END
```

77C

```
      SUBROUTINE WXR77C (QK,QB,QC,
     1 NZ,G,DELT,NSTEP,HAFDEL,DELSIX,IFTEST,
     2 RACT,RINB,RINC,QUENCH,ROUTB,ROUTC)
C     10.21.63  STRENGTHENED QUENCH AT 466 AND 467
C     10.15.63  MOD OF WXR73C
C     10.10.63  REPLACED ALL COMMON AND EQUIVALENCE WITH APPROPRIATE ARGUMENTS
C     AND CORRESPONDING DIMENSION STATEMENTS.  PROGRAMS OTHERWISE UNCHANGED.
C
C     9.26.63  10.2.63   10.4.63
C
C     RUNGE KUTTA FOR ACTIVE CHAIN
C
      DIMENSION QK(202),QB(202),QC(202),A(202),B(202),C(202),DQ(202,4),
     X DB(202,4),DC(202,4)
C
  400 JSTEP = 0
  405 NLZ=NZ-1
  406 IF(IFTEST) 407,410,407
  407 WRITE OUTPUT TAPE 15, 408, NZ, NLZ, G, DELT, NSTEP
  408 FORMAT (25HTEST PRINT WITHIN WXR73C.  5X, 3HNZ=, I3, 5X, 4HNLZ=,
     X I3, 10X, 2F10.5, I5 /)
  410 JR=0
  420 DO 430 JZ=1, NZ
  428 B(JZ) = QB(JZ)
  429 C(JZ) = QC(JZ)
  430 A(JZ) = QK(JZ)
  440 IF(IFTEST) 441,445,441
  441 WRITE OUTPUT TAPE 15, 941, JR, JSTEP
  941 FORMAT (24HARGUMENTS A,B,C FOR JR=  ,I1, 5X, 6HJSTEP=, I3)
  442 WRITE OUTPUT TAPE 15, 942, (A(JZ), JZ=1, NZ)
  443 WRITE OUTPUT TAPE 15, 942, (B(JZ), JZ=1, NZ)
  942 FORMAT (10X, (1X, 10F10.5))
  444 WRITE OUTPUT TAPE 15, 942, (C(JZ), JZ=1, NZ)
  445 JR = JR + 1
  450 DQ(1,JR) = G*(A(2)-A(1))-A(1)+RACT*B(1)*(1.1-A(1)) -
     X QUENCH*A(1)*C(1)
  460 DQ(NZ,JR) = G*(A(NLZ)-A(NZ)) - A(NZ) + RACT*B(NZ)*(1.1-A(NZ)) -
     X QUENCH*A(NZ)*C(NZ)
  465 DO 467 JZ=1, NZ
  466 DB(JZ,JR) = RINB*A(JZ)*A(JZ) - ROUTB*B(JZ) - QUENCH*B(JZ)*C(JZ)
  467 DC(JZ,JR) = RINC*B(JZ) - ROUTC*C(JZ) + QUENCH*C(JZ)*(A(JZ)+B(JZ))
  470 DO 480 JZ=2, NLZ
  480 DQ(JZ,JR) = G*(A(JZ-1)+A(JZ+1)-A(JZ)-A(JZ)) - A(JZ) + RACT*B(JZ)*
     X (1.1-A(JZ)) - QUENCH*A(JZ)*C(JZ)
  481 IF(IFTEST) 482,490,482
```

77C

78C

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  482 WRITE OUTPUT TAPE 15, 982, JR
  483 WRITE OUTPUT TAPE 15, 983, (DQ(JZ,JR), JZ=1, NZ)
  484 WRITE OUTPUT TAPE 15, 983, (DB(JZ,JR), JZ=1, NZ)
  485 WRITE OUTPUT TAPE 15, 983, (DC(JZ,JR), JZ=1, NZ)
  982 FORMAT (28HRUNGE-KUTTA DERIVATIVES. JR=, I1)
  983 FORMAT (10X, 10(3X, F8.2))
  490 GO TO (500,500,530,560), JR
  500 DO 510 JZ=1, NZ
  508 B(JZ) = QB(JZ) + HAFDEL*DB(JZ,JR)
  509 C(JZ) = QC(JZ) + HAFDEL*DC(JZ,JR)
  510 A(JZ) = QK(JZ) + HAFDEL*DQ(JZ,JR)
  520 GO TO 440
  530 DO 540 JZ=1, NZ
  538 B(JZ)=QB(JZ) + DELT*DB(JZ,3)
  539 C(JZ)=QC(JZ) + DELT*DC(JZ,3)
  540 A(JZ)=QK(JZ) + DELT*DQ(JZ,3)
  550 GO TO 440
  560 DO 570 JZ=1, NZ                                                       WXR71C
  568 QB(JZ)=QB(JZ)+(DB(JZ,1)+DB(JZ,4)+(DB(JZ,2)+DB(JZ,3))*2.)*DELSIX
  569 QC(JZ)=QC(JZ)+(DC(JZ,1)+DC(JZ,4)+(DC(JZ,2)+DC(JZ,3))*2.)*DELSIX
  570 QK(JZ)=QK(JZ)+(DQ(JZ,1)+DQ(JZ,4)+(DQ(JZ,2)+DQ(JZ,3))*2.)*DELSIX
  580 JSTEP = JSTEP + 1
  581 IF(IFTEST)582,590,582
  582 WRITE OUTPUT TAPE 15, 583, JSTEP, (QK(JZ), JZ=1, NZ)
  583 FORMAT (28HVALUES OF VAZ(JZ) FOR JSTEP=,I1, / 8X, 10(2X, F9.5) /)
  584 WRITE OUTPUT TAPE 15, 586, (QB(JZ), JZ=1,NZ)
  585 WRITE OUTPUT TAPE 15, 587, (QC(JZ), JZ=1,NZ)
  586 FORMAT (8X, 2HQB, 10(2X, F9.5))
  587 FORMAT (8X, 2HQC, 10(2X, F9.5)//)
  590 IF(JSTEP- NSTEP) 410,600,600                                          WXR71C
  600 RETURN
      END

      SUBROUTINE WXR78C (QK,
     1 NZ,G,DELT,NSTEP,HAFDEL,DELSIX,IFTEST)
C
C     10.15.63  MOD OF WXR74C
C     10.10.63  REPLACED ALL COMMON AND EQUIVALENCE WITH APPROPRIATE ARGUMENTS
C     AND CORRESPONDING DIMENSION STATEMENTS.  PROGRAMS OTHERWISE UNCHANGED.
C
C     9.30.63  MOD OF WXR71C       10.2.63    10.4.63
C
C THIS IS RUNGE-KUTTA COMPUTATION FOR PASSIVE CHAIN OF COMPARTMENTS      WXR71C
C JZ IS COMPARTMENTAL INDEX.  JR IS RUNGE-KUTTA INDEX.
C   THE A(JZ) REPRESENT SUCCESSIVELY ARGUMENTS FOR RUNGE-KUTTA COEFFICIENTS.
C     DELT REPRESENTS THE TIME INTERVAL DETERMINED FROM LARGEST RATE CONSTANT.
C DQ(JZ,JR) ARE SLOPES, WHEN MULT BY DELT THEY YEILD RUNGE KUTTA COEFICIENTS.
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C
      DIMENSION QK(202),A(202),DQ(202,4)
C
 400  JSTEP = 0                                                         WXR71C
 405  NLZ=NZ-1                                                          WXR71C
 406  IF(IFTEST) 407,410,407
 407  WRITE OUTPUT TAPE 15, 408, NZ, NLZ, G, DELT, NSTEP
 408  FORMAT (25HTEST PRINT WITHIN WXR74C.  5X, 3HNZ=, I3, 5X, 4HNLZ=,
     X I3, 10X, 2F10.5, I5 /)
 410  JR=0                                                              WXR71C
 420  DO 430 JZ=1, NZ                                                   WXR71C
 430  A(JZ) = QK(JZ)                                                    WXR71C
 440  IF(IFTEST) 441,445,441
 441  WRITE OUTPUT TAPE 15, 442, ( A(JZ), JZ=1, NZ)
 442  FORMAT (6HA(JZ)=  / (10F12.5))
 445  JR = JR + 1
 450  DQ(1,JR) = G*(A(2)-A(1)) - A(1)                                   WXR71C
 460  DQ(NZ,JR) = G*(A(NLZ)-A(NZ)) - A(NZ)                              WXR71C
 470  DO 480 JZ=2, NLZ                                                  WXR71C
 480  DQ(JZ,JR) = G*(A(JZ-1)+A(JZ+1)-A(JZ)-A(JZ)) - A(JZ)               WXR71C
 481  IF(IFTEST) 482,490,482
 482  WRITE OUTPUT TAPE 15, 483, JR, (DQ(JZ,JR), JZ=1, NZ)
 483  FORMAT (28HRUNGE-KUTTA DERIVATIVES. JR=, I1, / 5X, 10F11.2 )
 490  GO TO (500,500,530,560), JR                                       WXR71C
 500  DO 510 JZ=1, NZ                                                   WXR71C
 510  A(JZ) = QK(JZ) + HAFDEL*DQ(JZ,JR)
 520  GO TO 440                                                         WXR71C
 530  DO 540 JZ=1, NZ                                                   WXR71C
 540  A(JZ)=QK(JZ) + DELT*DQ(JZ,3)                                      WXR71C
 550  GO TO 440                                                         WXR71C
 560  DO 570 JZ=1, NZ                                                   WXR71C
 570  QK(JZ)=QK(JZ)+(DQ(JZ,1)+DQ(JZ,4)+(DQ(JZ,2)+DQ(JZ,3))*2.)*DELSIX
 580  JSTEP = JSTEP + 1                                                 WXR71C
 581  IF(IFTEST)582,590,582
 582  WRITE OUTPUT TAPE 15, 583, JSTEP, (QK(JZ), JZ=1, NZ)
 583  FORMAT (27HVALUES OF  VBZ   FOR JSTEP=, I1, / 8X, 10(2X, F9.5) /)
 590  IF(JSTEP - NSTEP) 410,600,600                                     WXR71C
 600  RETURN                                                            WXR71C
      END                                                               WXR71C
```